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Western Mining in the Twentieth Century Series

Frank F. Aplan

MINERAL EDUCATION GENERALIST, PROFESSOR OF METALLURGY AND MINERAL PROCESSING, 1951-1998

With Introductions by
Dr. Barbara Arnold
and
Dr. Douglas Fuerstenau

Interviews Conducted by
Eleanor Swent
in 1998

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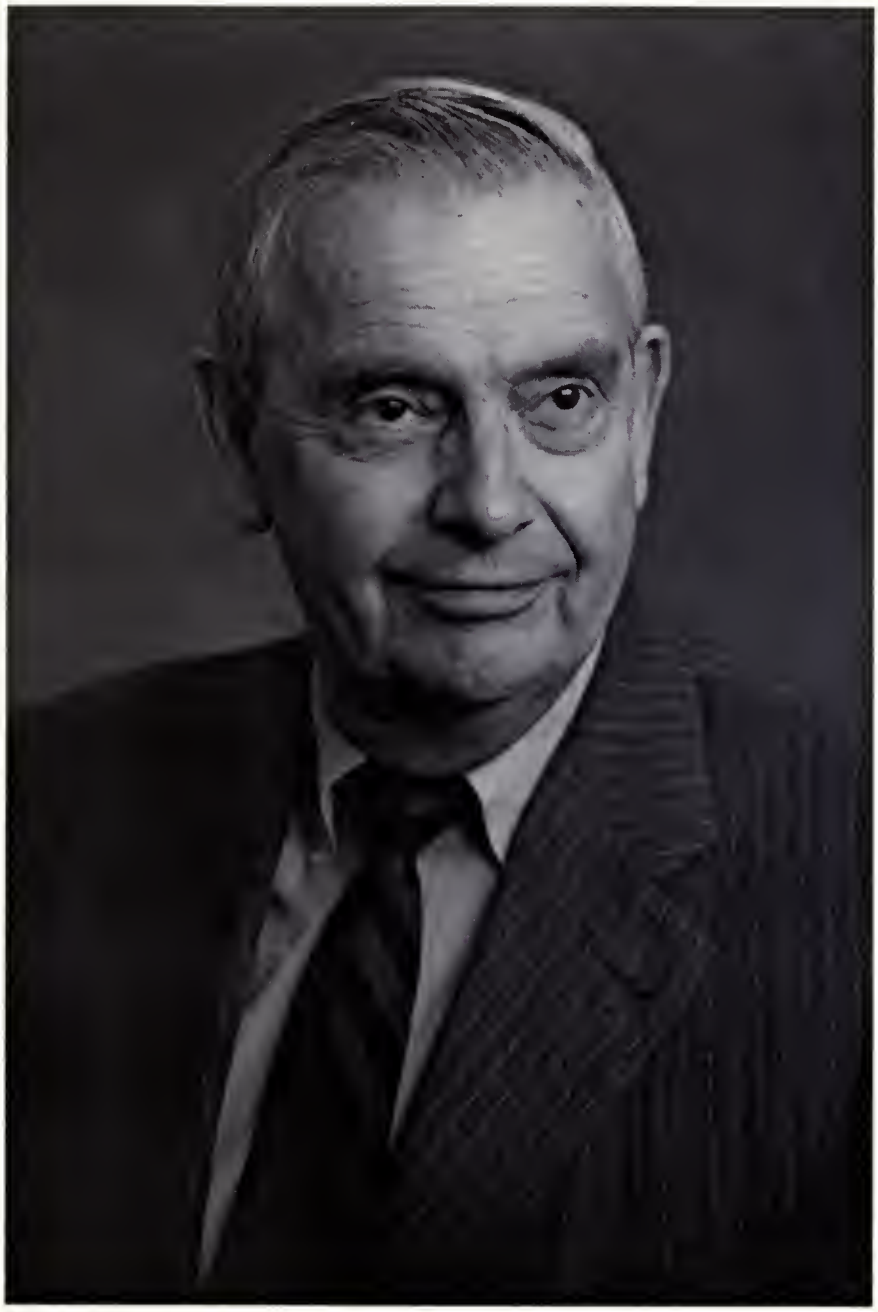

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PREFACE

The oral history series on Western Mining in the Twentieth Century documents the lives of leaders in mining, metallurgy, geology, education in the earth and materials sciences, mining law, and the pertinent government bodies. The field includes metal, non-metal, and industrial minerals. In its tenth year the series numbers thirty-five volumes completed and others in process.

Mining has changed greatly in this century: in the technology and technical education; in the organization of corporations; in the perception of the national strategic importance of minerals; in the labor movement; and in consideration of health and environmental effects of mining.

The idea of an oral history series to document these developments in twentieth century mining had been on the drawing board of the Regional Oral History Office for more than twenty years. The project finally got underway on January 25, 1986, when Mrs. Willa Baum, Mr. and Mrs. Philip Bradley, Professor and Mrs. Douglas Fuerstenau, Mr. and Mrs. Clifford Heimbucher, Mrs. Donald McLaughlin, and Mr. and Mrs. Langan Swent met at the Swent home to plan the project, and Professor Fuerstenau agreed to serve as Principal Investigator.

An advisory committee was selected which included representatives from the materials science and mineral engineering faculty and a professor of history of science at the University of California at Berkeley; a professor emeritus of history from the California Institute of Technology; and executives of mining companies. Langan Swent delighted in referring to himself as "technical advisor" to the series. He abetted the project from the beginning, directly with his wise counsel and store of information, and indirectly by his patience as the oral histories took more and more of his wife's time and attention. He completed the review of his own oral history transcript when he was in the hospital just before his death in 1992. As some of the original advisors have died, others have been added to help in selecting interviewees, suggesting research topics, and securing funds.

The project was presented to the San Francisco section of the American Institute of Mining, Metallurgical, and Petroleum Engineers (AIME) on "Old-timers Night," March 10, 1986, when Philip Read Bradley, Jr., was the speaker. This section and the Southern California section of AIME provided initial funding and organizational sponsorship.

The Northern and Southern California sections of the Woman's Auxiliary to the AIME (WAAIME), the California Mining Association, and the Mining and Metallurgical Society of America (MMSA) were early supporters. Later the National Mining Association became a sponsor. The project was significantly advanced by a generous bequest received in November 1997 upon the death of J. Ward Downey, UC Berkeley alumnus and early member of the mining series advisory committee. His own oral history was completed in 1992. Other individual and corporate donors are listed in the volumes. Sponsors to date include nineteen corporations, four foundations, and 113 individuals. The project is ongoing, and funds continue to be sought.

The first five interviewees were all born in 1904 or earlier. Horace Albright, mining lawyer and president of United States Potash Company, was ninety-six years old when interviewed. Although brief, this interview adds another dimension to a man known primarily as a conservationist.

James Boyd was director of the industry division of the military government of Germany after World War II, director of the U.S. Bureau of Mines, dean of the Colorado School of Mines, vice president of Kennecott Copper Corporation, president of Copper Range, and executive director of the National Commission on Materials Policy. He had reviewed the transcript of his lengthy oral

history just before his death in November, 1987. In 1990, he was inducted into the National Mining Hall of Fame, Leadville, Colorado.

Philip Bradley, Jr., mining engineer, was a member of the California Mining Board for thirty-two years, most of them as chairman. He also founded the parent organization of the California Mining Association, as well as the Western Governors Mining Advisory Council. His uncle, Frederick Worthen Bradley, who figures in the oral history, was in the first group inducted into the National Mining Hall of Fame in 1988.

Frank McQuiston, metallurgist for the Raw Materials Division of the Atomic Energy Commission and vice president of Newmont Mining Corporation, died before his oral history was complete; thirteen hours of taped interviews with him were supplemented by three hours with his friend and associate, Robert Shoemaker.

Gordon Oakeshott, geologist, was president of the National Association of Geology Teachers and chief of the California Division of Mines and Geology.

These oral histories establish the framework for the series; subsequent oral histories amplify the basic themes. After over thirty individual biographical oral histories were completed, a community oral history was undertaken, documenting the development of the McLaughlin gold mine in the Napa, Yolo, and Lake Counties of California (the historic Knoxville mercury mining district), and the resulting changes in the surrounding communities. This comprises forty-three interviews.

Future researchers will turn to these oral histories to learn how decisions were made which led to changes in mining engineering education, corporate structures, and technology, as well as public policy regarding minerals. In addition, the interviews stimulate the deposit, by interviewees and others, of a number of documents, photographs, memoirs, and other materials related to twentieth century mining in the West. This collection is being added to The Bancroft Library's extensive holdings. A list of completed and in process interviews for the mining series appears at the end of this volume.

Interviews were conducted by Malca Chall and Eleanor Swent.

Eleanor Swent, Project Director
Western Mining in the Twentieth
Century Series

January 1998
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Interviews Completed, February 2003

Horace Albright, *Mining Lawyer and Executive, U.S. Potash Company, U.S. Borax, 1933-1962*, 1989

Frank F. Aplan, *Mineral Education Generalist, Professor of Metallurgy and Mineral Processing, 1951-1998*, 2003.

Samuel S. Arentz, Jr., *Mining Engineer, Consultant, and Entrepreneur in Nevada and Utah, 1934-1992*, 1993

James Boyd, *Minerals and Critical Materials Management: Military and Government Administrator and Mining Executive, 1941-1987*, 1988

Philip Read Bradley, Jr., *A Mining Engineer in Alaska, Canada, the Western United States, Latin America, and Southeast Asia*, 1988

Catherine C. Campbell, *Ian and Catherine Campbell, Geologists: Teaching, Government Service, Editing*, 1989

William Clark, *Reporting on California's Gold Mines for the State Division of Mines and Geology, 1951-1979*, 1993

John Robert Clarkson, *Building the Clarkson Company, Making Reagent Feeders and Valves for the Mineral Industry, 1935 to 1998*, 1999

Norman Cleaveland, *Dredge Mining for Gold, Malaysian Tin, Diamonds, 1921-1966; Exposing the 1883 Murder of William Raymond Morley*, 1995

William E. Colby, *Reminiscences* (California mining lawyer), 1954

Harry M. Conger, *Mining Career with ASARCO, Kaiser Steel, Consolidation Coal, Homestake, 1955 to 1995: Junior Engineer to Chairman of the Board*, 2001

James T. Curry, Sr., *Metallurgist for Empire Star Mine and Newmont Exploration, 1932-1955; Plant Manager for Calaveras Cement Company, 1956-1975*, 1990

Donald Dickey, *The Oriental Mine, 1938-1991*, 1996

J. Ward Downey, *Mining and Construction Engineer, Industrial Management Consultant, 1936 to the 1990s*, 1992

Warren Fenzi, *Junior Engineer to President, Director of Phelps Dodge, 1937 to 1984*, 1996

Hedley S. "Pete" Fowler, *Mining Engineer in the Americas, India, and Africa, 1933-1983*, 1992

James Mack Gerstley, *Executive, U.S. Borax & Chemical Corporation; Trustee, Pomona College; Civic Leader, San Francisco Asian Art Museum*, 1991

Robert M. Haldeman, *Managing Copper Mines in Chile: Braden, CODELCO, Minerec, Pudahuel; Developing Controlled Bacterial Leaching of Copper from Sulfide Ores; 1941-1993*, 1995

John F. Havard, *Mining Engineer and Executive, 1935-1981*, 1992

Wayne Hazen, *Plutonium Technology Applied to Mineral Processing; Solvent Extraction; Building Hazen Research; 1940-1993*, 1995

George Heikes, *Mining Geologist on Four Continents, 1924-1974*, 1992

Helen R. Henshaw, *Recollections of Life with Paul Henshaw: Latin America, Homestake Mining Company*, 1988

Homestake Mine Workers, Lead, South Dakota, 1929-1993, interviews with Clarence Kravig, Wayne Harford, and Kenneth Kinghorn, 1995

Lewis L. Huelsdonk, *Manager of Gold and Chrome Mines, Spokesman for Gold Mining, 1935-1974*, 1988

William Humphrey, *Mining Operations and Engineering Executive for Anaconda, Newmont, Homestake, 1950 to 1995*, 1996

Hugh C. Ingle, Jr., *Independent Small Mines Operator, 1948 to 1999; Corona Mine*, 2000

James Jensen, *Chemical and Metallurgical Process Engineer: Making Deuterium, Extracting Salines and Base and Heavy Metals, 1938-1990s*, 1993

Arthur I. Johnson, *Mining and Metallurgical Engineer in the Black Hills: Pegmatites and Rare Minerals, 1922 to the 1990s*, 1990

G. Frank Joklik, *Exploration Geologist, Developer of Mt. Newman, President and CEO of Kennecott, 1949-1996; Chairman, Salt Lake 2002 Olympic Winter Games Committee*, 1997

Evan Just, *Geologist: Engineering and Mining Journal, Marshall Plan, Cyprus Mines Corporation, and Stanford University, 1922-1980*, 1989

Robert Kendall, *Mining Borax, Shaft-Freezing in Potash Mines, U.S. Borax, Inc., 1954-1988*, 1994

The Knoxville Mining District, The McLaughlin Gold Mine, Northern California, Volume I, 1998
Anderson, James, "Homestake Vice President-Exploration"
Baker, Will, "Citizen Activist, Yolo County"

Birdsey, Norman, "Metallurgical Technician, McLaughlin Process Plant"
Bledsoe, Brice, "Director, Solano Irrigation District"

The Knoxville Mining District, The McLaughlin Gold Mine, Northern California, Volume II, 1998
Cerar, Anthony, "Mercury Miner, 1935-1995"
Ceteras, John, "Organic Farmer, Yolo County"
Conger, Harry, "President, Chairman, and CEO, Homestake Mining Company, 1977 to 1994"
Corley, John Jay, "Chairman, Napa County Planning Commission, 1981 to 1985"
Cornelison, William, "Superintendent of Schools, Lake County" (Includes an interview with John A. Drummond, Lake County Schools Attorney)

The Knoxville Mining District, The McLaughlin Gold Mine, Northern California, Volume III, 1998
Crouch, David, "Homestake Corporate Manager-Environmental Affairs"
Enderlin, Elmer, "Miner in Fifty-Eight Mines"
Fuller, Claire, "Fuller's Superette Market, Lower Lake"
Goldstein, Dennis, "Homestake Corporate Lawyer"
Guinivere, Rex, "Homestake Vice President-Engineering"

The Knoxville Mining District, The McLaughlin Gold Mine, Northern California, Volume IV, 1998
Gustafson, Donald, "Homestake Exploration Geologist, 1975-1990"
Hanchett, Bonny Jean, "Owner and Editor, Clearlake *Observer*, 1955-1986"
Hickey, James, "Director of Conservation, Development, and Planning for Napa County, 1970 to 1990"
Jago, Irene, "The Jagos of Jago Bay, Clear Lake"
Jonas, James, "Lake County Fuel Distributor"
Koontz, Dolora, "Environmental Engineer, McLaughlin Mine, 1988-1995"

The Knoxville Mining District, The McLaughlin Gold Mine, Northern California, Volume V, 1998
Kritikos, William, "Operator, Oat Hill Mine"
Landman, John, "Rancher, Morgan Valley"
Lyons, Roberta, "Journalist and Environmentalist"
Madsen, Roger, "Homestake Mechanical Engineer"
Magoon, Beverly, "Merchant and Craft Instructor, Lower Lake"
McGinnis, Edward, "Worker at the Reed Mine"

The Knoxville Mining District, The McLaughlin Gold Mine, Northern California, Volume VI, 1999
Robert McKenzie, "McKenzies in Monticello, Berryessa Valley"
Harold Moskowite, "Napa County Supervisor"
Marion Onstad, "Neighbor and Employee of the McLaughlin Mine, 1980-1995"
Ronald Parker, "Resident Manager of the McLaughlin Mine, 1988-1994"
Richard Stoehr, "Homestake Engineer and Geologist to Senior Vice-President and Director"
Joseph Strapko, "Exploration Geologist, McLaughlin Mine Discovery, 1978"

The Knoxville Mining District, The McLaughlin Gold Mine, Northern California, Volume VII, 2000
Jack Thompson, "General Manager, McLaughlin Mine, 1981-1988"
Twyla Thompson, "County Supervisor, Yolo County, 1975-1985"
Avery Tindell, "Capay Valley Environmentalist"
John Turney, "McLaughlin Metallurgist: Pioneering Autoclaving for Gold"

Della Underwood, "Knoxville Rancher, McLaughlin Mine Surveyor"
Walter Wilcox, "County Supervisor, Lake County, 1979-1995"
Peter Scribner, "Boyhood at the Knoxville Mine, 1941-1944"

The Knoxville Mining District, The McLaughlin Gold Mine, Northern California, Volume VIII, 2002
Dean Enderlin, "Mine Geologist, Reclamation Manager, McLaughlin Mine"
Susan Harrison, "McLaughlin Natural Reserve"
Raymond Krauss, "Environmental Manager, McLaughlin Mine"

Marian Lane, *Mine Doctor's Wife in Mexico During the 1920s*, 1996

John Sealy Livermore, *Prospector, Geologist, Public Resource Advocate: Carlin Mine Discovery, 1961; Nevada Gold Rush, 1970s*, 2000

J. David Lowell, *Using Applied Geology to Discover Large Copper and Gold Mines in Arizona, Chile, and Peru*, 1999

Plato Malozemoff, *A Life in Mining: Siberia to Chairman of Newmont Mining Corporation, 1909-1985*, 1990

Donald H. McLaughlin, *Careers in Mining Geology and Management, University Governance and Teaching*, 1975

James and Malcolm McPherson, *Brothers in Mining*, 1992

Frank Woods McQuiston, Jr., *Metallurgist for Newmont Mining Corporation and U.S. Atomic Energy Commission, 1934-1982*, 1989

Gordon B. Oakeshott, *The California Division of Mines and Geology, 1948-1974*, 1988

James H. Orr, *An Entrepreneur in Mining in North and South America, 1930s to 1990s*, 1995

Vincent D. Perry, *A Half Century as Mining and Exploration Geologist with the Anaconda Company*, 1991

Patrick Purtell, *Maintenance and Management at the McLaughlin Mine, 1985 to 1997*, 1999

Carl Randolph, *Research Manager to President, U.S. Borax & Chemical Corporation, 1957-1986*, 1992

John Reed, *Pioneer in Applied Rock Mechanics, Braden Mine, Chile, 1944-1950; St. Joseph Lead Company, 1955-1960; Colorado School of Mines, 1960-1972*, 1993

Joseph Rosenblatt, *EIMCO, Pioneer in Underground Mining Machinery and Process Equipment, 1926-1963*, 1992

Robert Shoemaker, *Metallurgical Engineer: Union Carbide, Bechtel, San Francisco Mining Associates; Metallurgical Consultant, 1953 to 2000*, 2001

Eugene David Smith, *Working on the Twenty-Mule Team: Laborer to Vice President, U.S. Borax & Chemical Corporation, 1941-1989*, 1993

Simon Strauss, *Market Analyst for Non-ferrous Metals and Non-metallic Minerals, Journalist, Mining Corporation Executive, 1927-1994*, 1995

Langan W. Swent, *Working for Safety and Health in Underground Mines: San Luis and Homestake Mining Companies, 1946-1988*, 1995

James V. Thompson, *Mining and Metallurgical Engineer: the Philippine Islands; Dorr, Humphreys, Kaiser Engineers Companies; 1940-1990s*, 1992

William Wilder, *Owner of One Shot Mining Company: Manhattan Mercury Mine, 1965-1981*, 1996

Alexander M. Wilson, *Leading a Changing Utah Construction and Mining Company: Utah International, GE-Utah, BHP-Utah, 1954 to 1987*, 2000

Interviews In Process

Douglas Fuerstenau, metallurgist
Guy Harris, Dow/mining chemicals
Noel Kirshenbaum, metallurgist
Milton Ward, mining executive
Roy Woodall, geologist

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INTRODUCTION by Dr. Barbara J. Arnold

"It will be good for your soul!" This was not to be argued, especially since I had provided the information to formulate the hypothesis. Running one flotation test in distilled water led to another very significant variable (ions present in the water) and a repeat of the complete test matrix already run in tap water. Dr. Aplan walked in on my flotation experiments that were continuing for the third day in a row, took one look at me as the pipette bulb went flying, and left without asking how they were going. This was part of my master's thesis research and actually some of the most interesting work of my career. But it was also good for my soul--as were proofreading papers, reviewing journal articles, grading undergraduate labs and homework, and responding to "BJ, Old B, P, F, (buddy, pal, friend) come see me" notes. The amount of work involved was always a function of the number of B's, P's, and F's on the note.

Somehow, I never got to implement the "how-not-to-be a platoon runner" story. That's the one where you run as fast as you can toward the other platoon until you're out of sight, take a nap for a couple of hours, and then run up to the other platoon to deliver the message. You're never asked to be the platoon runner again.

There was certainly a lesson to be learned in that story and in all of the words of wisdom dispensed over the years: like vitamin C and alcohol in copious amounts are cures for the common cold and only fasting and prayer can heal tendinitis.

We all--Dr. Aplan's students and colleagues--have learned much from his words. But we have also learned much from his actions. Dr. Aplan required his graduate students to take experimental design from the agronomy department. We learned to apply the principles of statistics to corn and cows and radishes. But at the same time, we needed to think about applying these principles to coal and minerals. There were lessons in this. Always seek the best information and best sources. Look outside your discipline or small circle or company to get a broader perspective or a different solution to a problem.

Dr. Aplan's graduate students also had the privilege of moving Dr. Aplan's office as programs at Penn State changed locations. It was always critical that each pile be moved and placed exactly as it was in the previous office because Dr. Aplan's memory was excellent. We learned that you must have an exceptional memory in order to have a cluttered (that's putting it kindly) office. Most of us learned to be organized to keep up with Dr. Aplan's memory.

As Dr. Aplan faced life-threatening illness with a conviction that it wasn't going to beat him, we also learned much about living. We learned that you must face the hard things, not just the things that come easily. Why? Because, it will be good for our souls! Dr. Aplan's soul must be very hardy indeed!

I'm certain that you'll enjoy reading Frank F. Aplan's oral history--the history of a great researcher, engineer, scientist, teacher, mentor, and friend.

Barbara J. Arnold, Ph.D., P.E.
President, PrepTech, Inc.

Apollo, PA
November 2002

INTRODUCTION by Douglas W. Fuerstenau

Although Frank Aplan was born in Boulder, Colorado, he has always considered himself to be a native of Ft. Pierre, South Dakota. After graduating from high school across the Missouri River in Pierre, the capital of the state of South Dakota, Frank began his higher education in 1941 at the South Dakota School of Mines and Technology under the auspices of the ASTP program. But when that program was canceled, he was sent to Europe as an infantryman. He has long expounded on his experiences in the Battle of the Bulge and in reaching Kassel in Germany at the end of World War II. Following his discharge, he returned to the South Dakota School of Mines. I first became acquainted with Frank during his senior year upon my transfer to the Metallurgical Engineering Department in my junior year.

After receiving his B.S. degree in Metallurgical Engineering in 1948, Frank went to Butte to continue his studies at Montana School of Mines, where he had been awarded a teaching assistantship. Learning a little about Frank's program at Butte probably had some influence on my own decision to go to Butte a year later for a master's degree. In the summer of 1949, after I had graduated from South Dakota School of Mines and Technology, I had a summer job at the Bunker Hill Smelter in Kellogg, Idaho, and one Saturday afternoon two or three of us drove over to Wallace (Idaho) and dropped into a bar for a beer. And there was Frank Aplan, who was working that summer for Day Mines in Wallace. After our chance meeting, Frank drove over to Kellogg on numerous following Saturdays, and he and I visited various operating mills around that great lead-zinc-silver district -- including the Bunker Hill mill, the Sunshine mill, the Star mill, and the very old Morning mill, amongst others. At the end of the summer, we drove to Butte where Frank introduced me to Professor Donald McGlashan, under whom we both would carry out our research work, and then on to South Dakota for a few days of holiday before returning to Butte for the fall term.

During that year in Butte, Frank and I visited the large concentrating mill and also the smelter of Anaconda Copper Mining Company in Anaconda, went underground in one or more of the mines in Butte, visited the zinc plant in Great Falls, and the Mike Horse Mine of AS&R near Helena. At that time, Anaconda Copper completely dominated Butte and the entire region. Frank had a great interest in New Orleans jazz, and on Friday or Saturday nights we took in many a "concert" down at the C.O.D. in Butte. Professor McGlashan had an active, energetic and collegial research group of graduate students that year working on a range of interesting mineral processing problems. As I recall, these research problems were a good mix of fundamental and somewhat more practical problems faced by the copper mining industry. Frank and I both received our M.S. degrees from Montana School of Mines at the June 1950 Commencement, where Dr. Donald H. McLaughlin was the speaker.

I kept in touch with Frank during the following year and a half that he worked for Climax Molybdenum and the three years that he was an assistant professor at the University of Washington in Seattle. Our correspondence led to Frank's applying for admission to the graduate school at MIT in 1953 to continue his graduate education in the Mineral Engineering program of the Department of Metallurgy. I had just become an assistant professor in that department, and when Frank arrived in Cambridge that fall, he was our very first dinner guest. Frank studied mainly under Professors deBruyn and Gaudin and received his Sc.D. degree in 1957. The most significant event during Frank's time at MIT was his meeting Clare, whom he married in 1955. I was an usher at the wedding.

The last night that I was at MIT before my departure for Union Carbide, Frank and I were in the lab late trying to finish some measurements to test our concepts that a mercaptan might function as the collector for the flotation of chrysocolla, a copper silicate mineral. The experiments ended when the top of a volumetric flask broke and tore through one of my fingers that needed several stitches. It was only a few years ago that we finally published a paper on those results.

After Frank completed his graduate program at MIT, he joined Kennecott Copper Corporation in Salt Lake City as a senior scientist at the Kennecott Research Laboratory. Both he and Clare were not particularly happy in Salt Lake City, so I suggested that he come to Niagara Falls to work for Union Carbide in the Metals Research Laboratory. That resulted in a very successful ten-year period for Frank working on a wide range of ore processing problems for the company, starting as research engineer and rising to group manager, Mineral Engineering R&D for the Mining and Metals Division of Union Carbide, first in Niagara Falls and then at Tuxedo Park, New York. In addition to carrying out innovative research on factors that control the viscosity of ferrosilicon suspensions (and hence the separation efficiency) used in making heavy media separations, he was heavily involved with the development of new processes for asbestos production in California, processing ores of manganese, columbium (niobium), tin, tungsten, and various other metals of interest to Union Carbide.

In 1967, Dr. Elburt Osborn, vice president of research at Pennsylvania State University (and later director of the U.S. Bureau of Mines), came up to me at the annual meeting of the AIME and said that the Penn State faculty had strongly suggested me as department head for Mineral Processing there. I told Dr. Osborn that I did not want to leave Berkeley but that they ought to consider Frank Aplan, who had all the same degrees that I did. The outcome was that after Frank had completed ten years with Union Carbide, he joined the faculty at Penn State as head of the Mineral Processing Section of the Department of Mineral Engineering. Later he served a term as head of the Metallurgy Section in the Department of Materal Sciences there.

In 1968, both Frank and I were invited back to Butte where we received professional degrees of Mineral Processing Engineering (honoris causa). This was my first visit to Butte again after eighteen years, and we had an interesting time touring Butte with Don McGlashan and going through Anaconda's huge new concentrating mill now located in Butte. By the way, the commencement speaker on that occasion was Dr. Walter Hibbard, then director of the U.S. Bureau of Mines.

Upon arriving at Penn State, Frank established an active research program on the science and technology of mineral processing, and particularly in the area of coal flotation because of the importance of coal mining to the state of Pennsylvania. At the same time, one can point to major contributions in such areas as slurry stability and rheology, flocculation and dispersion, gravity separations, wetting phenomena, hydrometallurgy and the environmental impact of mining and mineral processing operations. His contributions are numerous, broad ranging, and widely acclaimed. At technical meetings, one could always count on an enthusiastic and dynamic presentation of papers on his research. Frank always tried to put a practical slant on most of work, making an attempt to flavor it towards the practicing engineer --- and particularly so with regard to coal preparation research. I recall unsuccessfully trying to suggest to him that he ought to rename his "Grab-and-Run" coal flotation process so that is sounded somewhat more scientific--- but he would have nothing to do with my suggestion. Frank's very extensive and wide ranging contributions to mineral and coal processing engineering and science have been recognized by his being awarded the Robert H. Richards Award of the AIME, Honorary Membership in AIME (he is only about the 200th person so recognized since 1872), the Antoine M. Gaudin Award and the Arthur F. Taggart Award of SME, and by election to the National Academy of Engineering.

His colleagues at Penn State consider, perhaps, the greatest contributions that Frank Aplan has made to the mineral processing profession have been as an educator. In his years at Penn State, he supervised about fifty M.S. and Ph.D. candidates and will be remembered by hundreds of others who took his courses. He always presented lectures with the typical Frank Aplan drive. Despite substantial teaching and research responsibilities, he dedicated much of his time to the development and well being of the mineral processing program at Penn State. He worked tirelessly at recruiting students into the field and in developing and teaching the courses and curricula needed to produce first-class mineral processing

engineers. His colleagues always give him major credit for establishing the leadership position of Penn State in the field. Amongst other forms of recognition, he received the Mineral Industry Education Award from AIME. Following his retirement, a group of former students, friends, colleagues and professional associates established and endowed the Frank R. and Clare M. Aplan Centennial Scholarship in Mineral Engineering at Penn State to express their recognition of Frank's contributions and to encourage future generations to follow his lead.

Frank also was a major contributor to the affairs of professional societies and to technical symposia and congresses. He has always been a strong believer in making sound presentations available to industrial practitioners, and generally slanted technical papers to emphasize their practical application. On any committee, you could always count on his enthusiastic and forceful presentations and suggestions. Frank was extremely active in Engineering Foundation conferences and as a member of the Board of the Engineering Foundation for many years. Because of his dedicated service as board chairman, the Engineering Foundation established the Frank F. Aplan Award as a tribute to his "lifelong productive career in coal and mineral processing research and education." I recall having the privilege of announcing this to Frank at an Engineering Foundation conference in Florida. Frank was the first recipient, and I had the honor being the next recipient the following year.

His many friends and colleagues know Frank as an outstanding human being. All of his friends have learned many lessons from Frank's two difficult but successful campaigns against cancer. He is a person one can always turn to for wise counsel and a helping hand. For many years, Frank and I have talked on the telephone every two or three weeks to discuss various approaches to professional problems that we might have been facing. His keen sense of humor and repertoire of stories and anecdotes can always be counted on for an enjoyable time in his company. Frank's interests extend far beyond his professional life; he is widely read, is a vociferous critic of politicians, an avid photographer, and a lover of jazz and theater. He has crawled around most of the old mills and ghost mining camps of the West. Before every SME annual meeting during the last many years, Frank always came a few days early to visit historical mining sites. Finally, not long ago, to express their thanks for his role in their lives and in the field of mineral processing, his friends and mineral processing colleagues around the world contributed papers to a special volume of the *International Journal of Mineral Processing* in honor of his seventy-fifth birthday. This certainly shows the how professional mineral processing researchers around the world have appreciated his role in the field.

Douglas W. Fuerstenau, Sc.D., Tekn.Dr.(h.c.)
Professor in the Graduate School
Dept. of Materials Science and Engineering

University of California
Berkeley, CA
January, 2003

INTERVIEW HISTORY by Eleanor Swent

Frank Aplan was recommended for inclusion in the oral history series on mining because of his uniquely extensive experience in process metallurgy, in operations, research, and teaching. He lists mining history as one of his principal hobbies; thus he links his career with his personal enjoyment, and views his work in a broad context, making him an ideal interviewee. At the beginning of the interview, he says, "I'm probably the last professor in the United States who has worked in a stamp mill." He says in his final interview, "I'm among the last of the mineral education generalists whose education cover this whole spectrum of geology, mining, mineral and metals processing, material science and product use. And because I have had a keen interest in the history of mining and metallurgy, I'm aware of what hasn't worked and what has worked and why."

The invitation letter to participate in the oral history series was sent on 20 May 1998, and the interviews were conducted in Professor Aplan's office in the Hosler Building on the Pennsylvania State University campus, University Park, Pennsylvania, on July 20-24, 1998. I was in Pennsylvania on a family vacation trip, and stayed at the venerable Nittany Lion Inn on campus. Frank Aplan and I have much in common: South Dakota roots and many mutual friends, including my father. We established rapport immediately, and interviewed for several hours each day, with a mid-day break. An unexpected bonus for me was the campus shop featuring products from the nation's oldest school of ice-cream making.

When the interview process was complete, the tapes were transcribed by our office and the lightly edited transcript was sent to him in June 1999 and returned in July 2001, with revisions, most of them simple semantic changes. He added a page of information regarding Anaconda Company's operations in Butte, and expanded the account of operations at Climax in Colorado. In his concern to give due credit, he added names of colleagues and students. He modestly deleted a heading "Earning the Bronze Star for Meritorious Service and Valor." The transcript was corrected, amended, and indexed at our office.

Funding for the interview was provided by United Engineering Foundation, and friends of Frank Aplan. Colleagues Dr. Barbara Arnold and Professor Douglas Fuerstenau provided introductions.

The Aplan interview is part of a series on Western Mining in the Twentieth Century; a complete list of volumes in the series is included in this volume. The Regional Oral History Office was established in 1954 to record the lives of persons who have contributed significantly to the history of California and the West. The office is a division of The Bancroft Library and is under the direction of Professor Richard Candida Smith.

Eleanor Swent, Senior Editor
Regional Oral History Office

The Bancroft Library
Berkeley, California
November 2002

Regional Oral History Office
Room 486 The Bancroft Library

University of California
Berkeley, California 94720

BIOGRAPHICAL INFORMATION

(Please write clearly. Use black ink.)

Your full name FRANK F APLAN

Date of birth 8/11/23 Birthplace BOULDER, CO

Father's full name FRANK F. APLAN (deceased)

Occupation ATTORNEY Birthplace RUSHVILLE, NE

Mother's full name HELEN E. (FISCHER) APLAN (deceased)

Occupation HIGH SCHOOL TEACHER Birthplace FORT PIERRE, SD

Your spouse CLARE MARIE (DONAGHUE) APLAN

Occupation HOUSEWIFE Birthplace BOSTON, MA

Your children PETER D. APLAN, SUSAN M. BOWER, LUCY A. APLAN, MARGARET ANNE APLAN (deceased)

Where did you grow up? FORT PIERRE, SD

Present community STATE COLLEGE, PA

Education B.S (MET.E) S.D. SCHOOL OF MINES & TECHNOLOGY; M.S, MINL.E. MONTANA SCHOOL OF MINES; ScD M I T

Occupation(s) DISTINGUISHED PROFESSOR EMERITUS OF METALLURGY AND MINERAL PROCESSING, THE PENNSYLVANIA STATE UNIVERSITY

Areas of expertise MINERAL AND COAL PROCESSING, HYDROMETALLURGY, EXTRACTIVE METALLURGY, SUSPENSION RHEOLOGY, PARTICLE TECHNOLOGY, ENVIRONMETAL REMEDIATION

Other interests or activities GHOST MINES, MINING HISTORY (ESPECIALLY WESTERN U.S., WORLD WAR II ~~HISTORY~~, NARROW GAUGE RAILROADS, JAZZ RECORDINGS, EXTENSIVE COLLECTIONS IN ALL OF THE ABOVE

Organizations in which you are active See attached listing

INTERVIEW WITH FRANK APLAN

I CHILDHOOD AND EDUCATION IN SOUTH DAKOTA, 1923 TO 1948

[Interview 1: July 20, 1998] ##[1]

A Pioneer South Dakota Family

Swent: We're in State College, Pennsylvania, on July 20, 1998, beginning an interview with Professor Frank Aplan. We'll start at the beginning, and ask you to tell something about your family background and your early years.

Aplan: I intend to do this chronologically more or less, and in that way you can see how I developed professionally and learned from successes, failures, and observations, to develop a philosophy of life. Basically, I try to look for a silver lining in every cloud, since you can often learn much more from your failures than from your successes. I am also going to stress that discipline, hard knocks, and a "make do" philosophy are wonderful, and as the old song goes, "pick yourself up, brush yourself off, and start all over again," is a good guide.

I was born in Boulder, Colorado, in 1923, while my father was attending law school at the University of Colorado. When I was about one year old we moved to Fort Pierre, South Dakota, which was my mother's home area. Her father was Frank G. Fischer, and with his two brothers Anton and Charles they formed the Fischer Brothers Company. Their store sold general merchandise: groceries, clothing, furniture, etc; they were pioneer merchants in South Dakota dating from 1882. In fact, three of my four grandparents were in Dakota Territory quite a few years before statehood in 1889. My maternal grandfather homesteaded in Stanley County.

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[1] ## This symbol indicates that a tape or tape segment has begun or ended. A guide to the tapes follows the transcript.

Swent: This is grandfather Fischer?

Aplan: Grandfather Fischer. My other grandfather Jens Ole Aplan, of Norwegian extraction, worked as a blacksmith in Gettysburg, South Dakota, in the early 1880s. He later homesteaded in Sheridan County, Nebraska.

Fort Pierre had a strong Western flavor, a strong pioneer spirit; you might describe it as a typical cow town. It had a population of about 850 and was across the Missouri River from the capital, Pierre, which had a population at that time of about 3,500. Today Fort Pierre has a population of about 2,500 and Pierre about 15,000--still the smallest state capitol in the United States.

Depression, Drought, Grasshoppers, and Self-Reliance

Swent: Yes, but historically very important.

Aplan: In a town like that you learned self-reliance, which was even more important because of the Depression, starting in 1929. To make matters worse, we had the drought which lasted for the decade of the 1930s, together with a plague of grasshoppers at the same time. They would eat everything, and could go through a cornfield in a day or so.

Swent: That was terrible.

Aplan: This was the dust bowl region. Stanley County lost about half of its rural population in the thirties. Together with the Okies there were also the Texies, the Dakoties, the Nebraskies, the Saskatchies, and the Alberties, etc., all going to the West Coast from the drought area which was the center strip of the U.S.A.

My father left the family when I was nine years old; my sister was four and my brother was one. Mother kept the operation together, and I saw how hard she worked to do that.

Swent: What took your father to Fort Pierre? What was your father doing in Fort Pierre?

Aplan: He was a lawyer. And my mother, I guess I would put her in for sainthood. She was a striver. She taught us the value of education, she taught us the philosophy of never quitting, and one of her little sayings I remember: "If a job is once begun, never leave it 'til it's done; be the labor great or small, do it well or not at all." She was a survivor. She died at age ninety-five a few years ago.

Swent: Did she go to work? Did she get a job?

Aplan: Oh, yes. This was the Depression, and she had to. She worked at first in the family store

as an accountant, and that would be a long day, from nine o'clock in the morning until six o'clock at night and on Saturdays nine to nine. In the late 1950s her hands became too arthritic for extensive bookkeeping, so she renewed her teaching certificate with courses at the University of South Dakota and became a high school English teacher and librarian.

Swent: Did you help at the family store, too?

Aplan: Oh yes, I put in my time, but mainly in summers.

My mother went through a lot in her life. Fort Pierre was flood-prone. The problem was the town was located at the juncture of Bad River (also called the Teton) and the Missouri. If the ice started to go out in the Missouri, but not completely, it would sometimes form a jam several feet higher than the normal river level. If Bad River was in flood stage at the same time, the water couldn't get out of the mouth of Bad River. So Mother went through floods in about 1905, and again in 1927 and 1952. During the flood of 1927, we lost our house. I wasn't yet four years old, but I remember being evacuated over the railroad track and I also remember them taking the tires off our Model T and they drove it across the railroad bridge on the rims, as the approach to the car bridge had been washed out. In the flood of 1952, Mother was evacuated by a National Guard DUKW.

Those floods are about at the end because the Oahe Dam, five miles north, now controls the Missouri River. The only flooding they've had in the area in recent years has been because of the procedure used by the Corps of Engineers to control water flow. Their first priority seems to be to help the people downstream from Omaha, rather than worry about those along the river in South Dakota. [laughs]

Fort Pierre was a good place to grow up. All the kids went hunting jack rabbits, bullheads, catfish--we didn't hunt bullheads and catfish, we fished for them. [laughs] And hiking. Since no one had any money we all became very inventive about things to do. In grade school, we would have about fifteen kids in a class, so let's say we had seven boys, that's not enough people out to play football, since we had staggered recess. We wanted to play football, so we developed a game called "Tackle the Man with the Ball." You lined up in two teams and as soon as the ball was snapped, the opponents and the man's own team members turned on him and tackled the man with the ball. [laughter]

The townsfolk were quite helpful. When I was a young child, probably about ten years old, my great aunt, who had kept house for my widower grandfather, was having some painting done by a local house painter by the name of Glenn Martin. Now he was kind of cantankerous sometimes, but somehow he took a shine to this ten-year-old kid. He had gone to Iowa State at the turn of the century but after two years he had to quit to help his mother and younger siblings after his father died. But he always had a great interest in chemistry. He had taken all of the International Correspondence School courses in chemistry and in those days there were a half dozen of them. He belonged to the American Chemical Society; and he took *JACS--Journal of American Chemical Society.* At about that time I had gotten a little Gilbert chemistry set, which I'm sure they don't make any more. The EPA [Environmental Protection Agency] is probably against all that

stuff, but it was a good learning experience for me. Glenn would talk to me, explain the purpose of the chemicals, and help me with experiments. Guy Loupe, the druggist, also helped me, so my interest in science was greatly sparked starting at about age ten.

I had gone to school in Fort Pierre through my junior year in high school and about this time I decided I wanted to go to the School of Mines. Since I couldn't get all the required courses in Ft. Pierre, I spent a year at Pierre High School and picked up physics, the second half of advanced algebra, plus trigonometry and French II, so I wouldn't have any deficits at the School of Mines. The local schools gave me a good education, and they had a lot of good teachers. This was a depression, so at that time, any job was a good job by definition, and so even a small school was able to hire some very, very good teachers. I was certainly blessed in that way.

Next item: in the fall of 1941, I went to School of Mines, in Rapid City, South Dakota, but in my freshman year the name was changed to the South Dakota School of Mines and Technology, SDSM&T.

Swent: You had mentioned that your father had something to do with coal mines.

Aplan: Yes, about 1931--times were tough then--and probably since he had been in the state legislature, he was appointed a state fire marshall. His job was inspecting some state-owned businesses, and in those days the state of South Dakota was into a lot of businesses: the Rural Credit Administration, the cement plant in Rapid City, and several coal mines, as well. There is a lot of lignite coal in the northwest part of the state and of course there were several private mines as well.

Swent: I see. So this was your first contact with coal mines?

Aplan: Yes. Okay, back to the School of Mines.

South Dakota School of Mines & Technology, 1941-1942, 1946-1948

Aplan: At that time, the school had the biggest enrollment it had ever had: 376, of which more than half were freshmen. [laughs] After the war it grew to 1,000 and then up to about 2,500 now, but in those days it was a fairly small school. As I said, I started out in chem engineering, but several things made me switch: a year of organic chemistry, for example. In those days you had to memorize everything and I hated memorization, so I always say that organic chemistry made a metallurgist out of me.

Though as a matter of fact it was a very valuable course because today I do use organic chemistry frequently. In hydrometallurgy and in flotation, you use a lot of organic chem , so the course in organic chemistry turned out to be extremely valuable although I didn't think so at the time. I then took a course in general metallurgy under Professor

Bancroft Gore. He was a real character but he was an excellent lecturer and extremely enthusiastic about metallurgy and this got me thinking. During World War II I had a lot of thinking time as I sat in a foxhole on the Siegfried Line and so on. When I got out of the army after World War II, I switched to metallurgy.

Meanwhile, back at the School of Mines--it was a small school, with many excellent, dedicated teachers. Those that particularly impressed me (but this isn't an all-inclusive list) were Bancroft Gore, and then in 1947, Jerry Van Duzee and Alex McHugh who were hired into the metallurgy faculty. Professor Gore had died in December, 1946, so I barely started back to school again, taking but one more metallurgy course when he died. Another teacher I greatly admired was Professor John Paul Gries in geology. He is still alive, still active, goes into his office every day. He is a wonderful human being, a tremendous geologist, well organized, and I well remember what he taught me fifty years ago.

The course selection in those days was highly restricted because the school was so small, so most everybody in school took very similar courses. In fact, the difference between mining, metallurgical, or geological engineering was very little and we all took many similar courses. I felt that was bad at the time, but afterwards I found out it was extremely valuable. For instance, why should I take a year of surveying? Why did I need a year of electrical machines? Et cetera, et cetera, et cetera. Well, I later found out why because they turned out to be very valuable to me.

Return to College as a War Veteran in 1946

Aplan: I enlisted November 2, 1942, at Fort Meade, South Dakota, and returned to college in September, 1946. As I mentioned, Professor Gore died in December at the end of the first quarter. He had been a one-man metallurgy department. The school had had a two-man met department before World War II, but Professor Kidd had left during the war. If you remember, things were very tight with colleges during the war and so they really stripped down the faculty. Thus, when I came back, Professor Gore was the sole metallurgy faculty member. So how did we finish out the rest of the term? Well, Professor Lincoln, F.C. Lincoln in the mining department--that was also a one-man department—served as pinch hitter. Charlie Bentley, who was an analyst in the Experiment Station, taught fire-assaying, and so forth. Kenneth Apland was a grad student and he also taught a course or two. Because we were mature vets, and well motivated, we also taught ourselves, especially in the labs.

Swent: Is Kenneth Apland a relative of yours?

Aplan: Kenny Apland was not a relative. His family comes from Belle Fourche, and they have a D on the end of the name. Well, my name originally had a D on the end of it, too. The family name was originally A-P-E-L-A-N-D. My great-grandfather dropped the E when

he came to the United States from Norway in about 1850. And my grandfather dropped the D when he worked as a blacksmith in Gettysburg, South Dakota, about 1881. He later went to Pine Ridge as a blacksmith and then settled in Rushville, Nebraska.

In the fall of 1941, Kenny Apland from Belle Fourche and Frank Aplan from Fort Pierre arrived at the School of Mines. There was considerable confusion. We were both in metallurgy--that is, after I switched to met--and our names would often get mixed up. The classic was one time when Ken made the top rank of the honor roll and the newspaper gave me the write-up. And so I went to Ken and said, "We certainly did a good job together on this one." [laughs]

The name is Norwegian, originally--Apeland. And there are two farm communities named Apeland in Norway. One of them is across the fjord from Stavanger on the west coast, and I believe that's where Ken's family came from, while the other is on the east coast, southwest of Oslo near Gjerstad. That's where my great-grandparents Ole Jensen Apeland and Ingebor Torjesdatter came from.

For our senior year, the school hired Jerry Van Duzee and Alex McHugh. Van Duzee taught physical metallurgy and McHugh taught process metallurgy. After graduation I kept in touch with both of these gentlemen. Even after I graduated, when I was living in either in Butte or later in Seattle, I would stop off to see them as I came through Rapid City. Since Jerry was a jazz enthusiast, he and I had developed this commonality of interest in jazz, so I would stop off in Rapid City and over a few Scotches we would listen to jazz records until the wee hours of the morning. After he left SDSM&T and went to work for Curtiss-Wright in Connecticut and I was at MIT [Massachusetts Institute of Technology], we would meet at AIME [American Institute of Mining, Metallurgical, and Petroleum Engineers] meetings in New York and go hit the jazz joints, so it was quite interesting. Later, Farlow Davis, a mining graduate of SDSM&T and the University of Washington, would join us.

For our senior project, a couple of us worked on pegmatite mineral separation by flotation and we were helped on that a project by Jerry Munson. There was a small U.S. Bureau of Mines station on campus and Jerry Munson handled the processing of pegmatites. We also had a cyanide pilot plant, an old one, in the Mining and Metallurgy building. It was all belt driven. It had one prime mover, and everything else was done with pulleys and belt drives. Doc Lincoln, who knew where all of the gold mines in the Black Hills were, took us out to Keystone and we went to a mine just around the corner from the Holy Terror. We brought back a few tons of ore, crushed it, and put it through the mill. It took seven metallurgy seniors (Ted Brooks, Bill Elliott, Sam Elrod, Jack Lowery, George Schmid, Ralph Shephard, and myself) and three cases of beer to run that pilot plant. [laughter] Cliff Flittie, Bob Hamilton, and Keith Papke, the three seniors in mining engineering, would pop in to give us moral support and friendly advice and help drink the beer. This last spring I was at my fiftieth reunion. There had been seven of us in metallurgy. Three had died and two of us attended--George Schmid and myself--so that gave us a 50-percent turnout of the metallurgists.

We also took several metallurgy and geology field trips in the Black Hills. Professor Paul Gries would take us on field trips to the pegmatites and of course the School of Mines always had a field trip connected with paleontology in the Bad Lands. We had a senior metallurgy trip to Colorado where we saw the Asarco-Globe smelter outside of Denver where they produced cadmium, indium, germanium, gallium. We also saw the Climax molybdenum mine and mill at Climax, where I later went to work. We also saw the New Jersey Zinc Company lead-zinc operation at Gilman, up near Tennessee Pass. There were several School of Mines graduates working in the underground mill there at the time, including Kenny Apland and Jack Nelson. After a visit to the Asarco Arkansas Valley lead smelter at Leadville, we went on to see the gold operation at Cripple Creek, followed by the iron and steel operations of the Colorado Fuel and Iron Company at Pueblo, where our guide was plant metallurgist Francis Eickelman, whom I had previously known at SDSM&T. Last, we went to the Colorado School of Mines at Golden to see the operations of A.J. Weinig and Bob Cuthbertson. I'll talk about them later, because they were also the research department for Climax Molybdenum Company.

Our commencement speaker was General Pick of Pick-Sloane fame, who was in charge of developing the Missouri Valley Dam system.

School of Mines Leaders in Research and Publication

Aplan: I should digress a minute and talk some about the School of Mines. I've always been interested in history of the West--Black Hills history and ghost mines especially. I've visited many ghost mines, I do a lot of reading on the history of the West, and I have a big collection of books on the Black Hills. Fortunately, we have an excellent library here at Penn State on mining subjects going back to about 1890, and so I have access to many of the old journals and can easily find information on old mines. My search has been greatly helped because there had been a very aggressive faculty at the South Dakota School of Mines in the early days and they wrote a great deal about Black Hills mining and metallurgy.

For instance, if you compare the early published papers from the South Dakota School of Mines with those of the Colorado School of Mines, you'll find almost nothing from the Colorado School of Mines, whereas there is this a tremendous amount from SDSM&T. It's impressive that with only a small faculty and but a few students, this small college in a remote location in the Western frontier and with marginal facilities and finances, showed they could compete with the best, and they did. They had an active research program in processing gold ores, in mineral analysis, geology, mineralogy, cartography, physical metallurgy, and they had an aggressive publication record of in-house research and of the latest technological developments in the Black Hills. Many of the earliest innovations in cyanidation were made in the Black Hills.

I spent considerable time in the library checking old *Transactions* of the AIME. In

1888, seventy-eight pages of the *Transactions*--this was the New York meeting--or 20 percent of the pages in that *Transactions* were by South Dakota School of Mines faculty. The railroad was just coming into--

Swent: For heaven's sake! It wasn't even a state yet; it was still a territory.

Aplan: Right! They started in '85 as the Dakota Territorial School of Mines. In the 1888 *Transactions*, Carpenter, who was the dean, i.e., president, and two geologists, Hadden and Hoffman, published all that material. In the next year, Hoffman alone published fifty-two pages in AIME *Transactions*. Hoffman later went back to MIT and headed up the metallurgy program there. At the turn of the century he wrote classic volumes on both lead and copper metallurgy.

You'll find pages and pages in subsequent volumes but the work by Zay Jeffries starting about 1918 stands out. Jeffries came from Fort Pierre, actually Stanley County, rural Stanley County. He rode a mule to the School of Mines about 1905. His biography that the American Society for Metals published a few years ago says it was a horse but everybody I know says that it was a mule. He rode that mule to the School of Mines and he took metallurgy. He then went to Case--that we now call Case-Western Reserve. At that time it was called Case Tech. He and another student by the name of Fahrenwald were among the first doctorates in engineering in the United States, both in metallurgy at Case. They had followed Professor Fulton back to Case about that time. Fulton left the School of Mines in 1911--so he must have taken these two graduates from the School of Mines back with him. [laughs] He saw that they were very smart guys. In World War I Zay Jeffries was probably the nation's leading authority on aluminum. He was later a vice president of Alcoa and then a vice president of General Electric, so did pretty well for a little boy from a little town.

Swent: Yes, he certainly did.

Aplan: Jeffries and J.V.N. Dorr in 1919 published about 20 percent of all the papers published that year by AIME. [laughs] They kept up the tradition of an energetic publishing program.

I've really been especially interested in the period from 1885, when the school was founded, until about 1920. Even though the School of Mines now gives more than a dozen different degrees, there were essentially only two degrees given in that period: mining and metallurgy. Civil and electrical engineering programs were started about 1918, but they had only one or two graduates at that time, so nearly all the graduates were in either mining or metallurgy.

The school had many interesting people. One of them--the fifth dean in 1893 was Walter P. Jenney who had been co-leader of the Newton-Jenney expedition into the Black Hills in 1875. This journey of discovery followed the Custer military expedition of 1874, and it was developed by the government to evaluate the flora, fauna, and mineral wealth of the Black Hills.

Then the first dean of the school from 1886-89 was Franklin Carpenter, who did a lot of publishing. He developed the pyretic smelting process that was used at the Deadwood and Delaware Smelter at Deadwood and was also used at the National Smelter in Rapid City. This latter smelter was located just off campus to the East and up the hill from the present football field. The slag from the smelter is now underneath the football field.

I've already mentioned Hoffman and the work he did. Another school leader that was interesting was Valentine T. McGillicuddy. McGillicuddy was a medical doctor and an engineer who was also the cartographer with the Newton-Jenney expedition. He was the first person to scale Harney Peak. In fact, his ashes are buried there as noted by a plaque close to the top. But let me digress a second; it's interesting how they got to the top of Harney Peak. You've probably climbed Harney Peak?

Swent: Not recently, but I have, yes.

Aplan: You'll remember that the last part is steep, but stairs put in by the WPA [Works Progress Administration] in the thirties make it an easy climb now. But originally there was just a granite spire—so how do you get to the top? To accomplish this they felled a tree onto the spire and climbed the branches of the tree to get to the top. In addition to being an army surgeon and engineer, McGillicuddy was also the Indian agent on the Pine Ridge Reservation in the early 1880s, and he attended the wounded at the Wounded Knee Massacre. In '96 he was mayor of Rapid City. His wife wrote a book called *McGillicuddy Agent* which was published by Stanford Press in 1941 which has recently been reissued as *Blood On the Moon*. You can get it in paperback. From 1893 to 1897, McGillicuddy was Dean of the School of Mines as well as being mayor of Rapid City for a year or two.

Then Charles Fulton was school president from the turn of the century until about 1911. He did a tremendous amount of work on the cyanide process and on the smelting process that was used in the Black Hills.

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Aplan: The next person I'd like to talk about is Galen H. Clevenger. His son, also a Galen but with a different initial, is still alive, though retired, and as a graduate student at MIT I knew the younger Clevenger in Boston since he worked for the AEC lab at Winchester, Mass. The original Clevenger's grandson is Jeffrey Clevenger, who's now the president of Amax-Climax Metals Company.

Well, the original Clevenger came as a young child to the Black Hills in about 1875. He worked as a miner for a while and then enrolled as a student at the School of Mines and began doing cyanide research. Now this was about 1899, so the cyanide process had only recently been introduced, so for everybody it was sort of amateur night. His senior research project was published as *Bulletin Number 3* of the School of Mines.

He noticed that just below the smelter, near the river just east of the campus, was a big tailings pile left over from an old gold chlorination process plant. Before cyanidation they either had to smelt the ore to recover the gold or use chlorination as mercury amalgamation would not recover all the gold. There were also gold chlorination plants at Deadwood, Pluma, Mystic, and Rapid City. Well, after sampling those tailings he cyanided them using whiskey barrels to hold the ore. [laughs] He then rounded up backers to help finance his construction of a twenty-ton-a-day pilot plant which he ran. By treating those tailings he made about $3,800 in two summers while still a student! Now $3,800 at $18-20 per ounce of gold would be worth roughly $55,000 today with gold approaching nearly $300 per ounce! That's pretty good for a student summer job! Now he had to pay some debts and so forth, but it certainly helped support him through the school.

He was later superintendent at the Mogul-Horseshoe Mill at Trojan, on the flank of Terry Peak. It's interesting, because at the same time J.V.N. Dorr was at the Lundberg, Dorr & Wilson Mill only a short distance away, also on the flank of Terry Peak, and Charles Merrill was working on cyanidation at Homestake at Lead, only a few miles away. Clevenger then became a professor at Stanford and wrote a classic paper with Coe on the design of a thickener, and they're still using that method today. We now have some better methods, but if you want a quick, fast method, the Coe and Clevenger method is it. He then later became a consulting engineer and finished out his professional life with for USSR & M, the United States Smelting, Refining, and Mining Company.

Then I should also point out that J.V.N. Dorr received an honorary doctorate in 1940 from the School of Mines. As a youth, Dorr worked for Edison at his New Jersey laboratory, got a bachelor's degree from Rutgers, and came out to the Black Hills in the early 1900s. He co-owned the Lundberg, Dorr & Wilson Mill at Terry where he invented the rake classifier, the thickener, and the air-lift agitator in about 1904 or 1905.

So the next one that I should mention is C.C. O'Harra. He came to the school in 1898 and he was president from 1911 until he died in 1935. He was a fantastic geologist. He wrote *Geology of the Black Hills*, concluding with *The Mineral Wealth of the Black Hills*, which he co-authored with fellow faculty member J.P. Connolly in 1929. He also wrote a book on the White River Bad Lands in 1910 and updated it in 1920. You can go to the Wall Drugstore today and buy that book. Wall Drug had it reprinted because it's still the best thing available on the Bad Lands and the paleontology and geology of the Bad Lands. He probably more than anyone else put the School of Mines on the map.

O'Harra was followed as school president by J.P. Connolly, who was president from 1935 until he died in 1949. When I came back to the School of Mines after World War II he was the president. And he, too, died shortly after Bancroft Gore. Anyway, I'm just impressed by what the people at my school did.

Swent: It is impressive, isn't it? The alumni are prominent all over the world.

Aplan: One other I should probably mention is "Doc" Lincoln. Though Doc Lincoln didn't come to the School of Mines until 1923. F.C. Lincoln had graduated from MIT in 1900 and

then got a doctorate from Columbia in geology. And he too was a very prolific publisher. He was a geologist for the State of Nevada for a number of years, and the bulletin he wrote in 1923, *Mining Districts and Mineral Resources of Nevada*, is still in print today. The reason for the longevity of this publication is that he had reported on every gold discovery in Nevada. The Nevada gold craze started when the price of gold was allowed to rise to free market levels in 1975. Exploration geologists used the philosophy, "If you want elephants, go to elephant country," so they went to where mines had been reported and then started--because now they could treat gold running less than a gram a ton whereas before they couldn't do that. When the heap-leach technology came in, they were able to treat ores containing less than a gram a ton of gold per ton economically.

Lincoln then came to the South Dakota School of Mines where he was a one-man mining department until he retired in 1949. For a few years prior to the war he was helped by Bob Kidd, a graduate of the Texas College of Mines (now UTEP), who was assistant professor of mining and metallurgy. I have already pointed out that Lincoln taught all mining courses, plus some of the metallurgy courses after Bancroft Gore died, and in addition, he completed and published seven Reports of Investigation for the Bureau of Mines. During the war he had done work on the lead-zinc deposits in the Wisconsin, Illinois, Missouri, Kansas lead-zinc belt, and these were published in the 1946-1948 era. So here's a guy, seventy years old [laughs] and doing all that teaching and all that publishing--I don't know how he did it!

One other I probably should mention that worked in that period is A.I. Johnson. And you did his oral history a few years ago. [Arthur I. Johnson, *Mining and Metallurgical Engineer in the Black Hills: Pegmatites and Rare Minerals, 1922 to the 1990s*, Western Mining in the Twentieth Century series, Regional Oral History Office, University of California, Berkeley, 1990] A.I. Johnson, who came from Lead, was born in 1899 and he started to the School of Mines during World War I and graduated in 1922. He was a prolific writer. If you look at the old issues of the *Pahasapa Quarterly* which the school published--I have collected most of those old publications and he had done a tremendous amount of writing when he was a student. For years many years he was known as the "Dean of Mining Engineers in the Black Hills". He'd worked for the old Holy Terror as manager and he worked for an arsenic plant, also in Keystone. Over the years he worked on the Bob Ingersoll, the Golden Slipper, the Black Hills Tin Company, the Mineral Mills and other mica operations during World War II, and he developed the process for floating spodumene at Tinton. He was state mine inspector for a number of years. In the period of 1969 to 1988, when he was in his seventies and eighties, he was a regular contributing author to the Dakota History Conference volumes. He wrote the last of nearly a dozen of these papers when he was eighty-nine! Talk about a producer who kept going even though others his age would be considered "over the hill."

Swent: Well, he lived to be very old.

Aplan: Yes, and for several years until he died in 1992, he was the oldest living graduate of the school.

[The following paragraph was added by Frank Aplan during his review of the draft transcript:

I guess the bottom line is that I am immensely proud to be a graduate of the South Dakota School of Mines and Technology. It is a small technical school that, for more than a century, has provided the youth of that state with a quality education and at low cost. I received an excellent education there and I am pleased to note that the quality remains high to this day. In particular, the Metallurgical and Materials Engineering program is a strong one with an excellent faculty. Ken Han is now department head.]

Summer Jobs at Homestake: "Walking Feed" on the Stamp Mill

Aplan: Okay, let me talk about Homestake. One thing I have to know is: what shall I call the boss? Shall I call him Mr. Herz, Nathaniel Herz, or your father?

Swent: [laughs] Well, I guess whatever you feel comfortable doing, that's fine.

Aplan: I certainly wouldn't have called--in those days, you know, the boss was called "Mister." I wouldn't have thought of calling him Nat or anything like that. I would be out at the end of the runway flapping my wings trying to get airborne before I would do that. [laughter]

Swent: And people wore suits to work.

Aplan: Oh, yes, the senior management always did.

Swent: Ties--the whole works.

Aplan: Yes, always did.

Swent: That was the old way.

Aplan: That's right.

Swent: And people worked together for their whole career and they referred to each other as "Mister."

Aplan: Yes, yes. When I was a junior in college, we had a field trip to Lead. I was quite impressed with that operation and so I drove up and asked Mr. Herz for a summer job, first in 1947 and later in 1948. At that time Mr. Herz was chief metallurgist, which today we would call mill superintendent--or superintendent of mills would be a better way of saying it since there were several mills under his supervision. Claude Schmidt was in charge of the South Mill, which was the crushing plant with stamps, and rod, ball, and tube mills. Frank Howell was in charge of Cyanide One and Cyanide Three. The Deadwood Slime Plant treated the very fine or slime product by cyanidation in filter

presses, a process developed years before by Charlie Merrill. They also ran a CCD [counter-current-decantation] pilot plant in the old Cyanide Three building.

I was very fortunate. Your father saw to it that I was moved around that entire milling operation and so I got a broad experience. The first year I was there I worked in the South Mill, first on the bull gang, then I walked feed on the stamp floor, and finally as a rod mill operator. The second year I worked in the cyanidation plants.

Swent: What do you mean "walked feed"?

Aplan: Well, what was done was to feed about 2 1/2-inch ore to the stamps which had about a 5/8-inch discharge screen, so the stamps were actually used as a tertiary crusher. Each stamp battery of five stamps had a rotating table feeder that fed the 2 1/2-inch stuff into the stamp battery and sometimes wood would prevent the ore from getting to the stamp; remember, at that time they used square sets in the mine. Wood was supposed to be removed before crushing but sometimes the wood would get by the system and show up in the stamp feed. If a piece of wood got hung up in the feed chute so no feed was coming in, then you had steel crushing on steel with water in between which would snap the stamp stem. Now that stamp stem was nearly twenty feet of about 3 ½ - to 4-inch steel. A single stamp weighed about 1,800 pounds with the tappet, the boss, and the shoe which pounded on the die. That whole thing weighed about 1,800 pounds; these were some of the biggest stamps made for gold ore crushing, and with thirty-six batteries of five stamps each they made a lot of noise. As you know, you could hear the stamp mill all the way to Deadwood on a still night.

Swent: Yes! I remember!

Aplan: So someone had to walk feed to make sure that no stamp was crushing without ore in the mortar because you didn't want to snap the stamp stems, because to tear down that stamp and replace the stem--that was a big drag. All the material had to come down an incline cog-line; it was an angle hoist and everything had to come down there, so you had to put those stamp stems, the boss, the shoes, and the dies, that all had to come down on that little cart. So if you snapped the stamp stem, it was a lot of work to replace it! You didn't want that, so you had to "walk feed".

The company had a no-smoking rule. You could only smoke in the change house or lunch rooms and so a lot of people chewed tobacco. When I was on the stamp floor, the shift boss would come up and give me my orders by yelling in my ear. As he chewed Beechnut, so then I had to muck out my ear. [laughs] From the Beechnut!

Swent: Oh, dear! [laughter]

Aplan: He was a good shift boss so I didn't mind. But most of the time I worked on the bull gang and then I was relief operator on the rod mills.

Swent: I guess in those days they didn't think anything about the damage this did to people's ears,

did they?

Aplan: I don't think it did much damage, quite frankly. I have hearing loss now, number one, because of age and number two, because I was a 60-mm-mortar gunner in World War II.

Swent: But nobody wore ear protectors around the stamp mills, did they?

Aplan: No, nobody wore any ear protection, but I don't think it caused me any damage. It might have, but I don't think so.

I'm probably the last professor in the United States who has worked a stamp mill.

Swent: I think that was one of the last mills to have stamps, wasn't it?

Aplan: It was. And so I've often taken great pride in that. For a while I claimed I was the only U.S. professor with stamp experience, until one of my friends, Terry McNulty, who is also a mining history buff, pointed out that Reinhard Schuhmann had worked in a stamp mill in Colorado near Pitkin, Colorado, in about 1936 when he was a student at Montana School of Mines. Schuhmann was later professor at MIT and still later at Purdue. When Schuhmann died, I can claim I'm the only living metallurgical professor with gold stamp experience.

Kind of an interesting story--we used to push new rods into the mills just after lunch, at about twelve-thirty. The rod mills in the South Mill were in closed circuit with Dorr rake classifiers. At about 12:20 one day I was standing around waiting for a time to push rods and I was watching a rake classifier when another summer employee who was named Burr Hardin came up to me and I said, "If you invent something like this, you'll be set for life." Well, a little later Burr showed me a picture of his son being held by his great-grandfather. It was J.V.N. Dorr--so Hardin was J.V.N. Dorr's grandson, so he was set without developing a rake classifier! [laughs]

Learning at the Counter-Current-Decantation Pilot Plant

Aplan: During the summer of 1948, after I had graduated from school, I worked in Cyanide One and Three. Again, I spent the first several weeks on the bull gang. Oh, I should interrupt here; when I worked in the bull gang of the South Mill, the bull gang foreman was Sven Wanhanen. I don't know if you knew him or not, but he was a tremendous human being. He knew <u>everything</u> about that mill and could do <u>anything</u> and could always make it go!

The second year at Homestake after a few weeks on the bull gang, I worked as relief operator, as a sluicer, to make sure that the vats were properly filled with ground, deslimed ore. Then I spent the rest of the summer working on a CCD pilot plant. The Deadwood Slime Plant was about ready to fall down and so they knew they were going to

have to have an alternate process and they looked at counter-current decantation. They had a CCD pilot plant running and I was able to work on that pilot plant. Frank Howell, the plant superintendent, would come up and go over the economics of why they were doing it, et cetera, so I gained a wonderful experience.

Years later when they abandoned amalgamation, they finally settled on jigging in the grinding circuit to recover coarse gold, followed by vat cyanidation for the sands and carbon-in-pulp for the slimes. They didn't use the CCD. All the way through, your father, Claude Schmidt, and Frank Howell saw that I was moved around the entire operation and got to participate in almost all phases of the operation, and they would often stop by and spend a little time educating me. Also your father saw to it that I could get underground to see the shrinkage stopes and square sets they were using at that time. A few years ago Al Winters saw to it that I got underground again and of course I wanted to see the vertical crater retreat and the cut and fill stopes that they are now using.

During my day off, I would drive my 1937 Olds around the Black Hills. I went up to Tinton when the spodumene flotation mill was still there, before it burned down; it was very fascinating. And then I had an interesting experience. I was driving down what is now U.S. 385--it was 85A at the time--down the spine of the Black Hills when I got to Pactola--now this was before they built the dam which flooded the old town site, and there was a little store and the railroad ran through town. The Crouch Line or the Rapid City, Black Hills and Western went from Rapid City to Mystic, all twenty-five, thirty miles of it, I guess. And suddenly I had to stop; the train was blocking the road. Pretty soon the cars started stacking up but the train still sat there. Finally out of the little store came the engineer, fireman, brakeman, and conductor licking on ice cream cones [laughter] and they got into the engine and went on down the tracks. The Crouch Line was kind of a run-down operation.

Swent: Crouch?

Aplan: The owner was Crouch. It was really the Rapid City, Black Hills and Western. And they used every piece of old equipment in the world. I used to ride the thing up to Silver City where my grandfather rented a summer place. I remember that sitting beside the track about where the river cuts the hogback at Rapid city they had a locomotive with the cone-shaped funnel stack. [laughs] They had all kinds of old equipment on that line.

Swent: Were they burning coal, I suppose?

Aplan: Yes, yes. [laughs] The other interesting thing is that from about where the Pactola Reservoir is now there was a wooden-stave flume that fed the Black Hills Power and Light hydro station in Power House Gulch just outside of Rapid City down from where Johnson Siding is today. The old hydropower plant building is still there and you can still see a small part of the flume that fed it. Well, during the thirties, no one had any money to fix the flume, and the flume leaked like a sieve. The RCBH & W had a kind of open-air car--it had a roof on it, but the sides were open--and when you went under that flume, you got a shower. [laughter] At the end of that time I went to Montana School of Mines.

Swent: When you got this job at the Homestake, what sort of hiring procedure did you have to go through and how much were you paid?

Aplan: Well, the first thing I did was write your father, Mr. Herz, for a job. The first guy would probably get the job. Then you had to go to the Homestake hospital which was kind of across the street from the main office, and pass a physical, quite a rigorous physical. Then I was paid the magnificent sum of ninety-six cents; that was the laborer's pay, except when I worked on shift work.

Swent: Ninety-six cents per hour?

Aplan: Yes, but as a matter of fact I saved more money percentage-wise than probably for years to come. And then I think I got up to $1.29 when I did some of the relief operating, so I was really in fat city. That was pretty good pay at the time.

Swent: What sort of clothes did you wear when you worked?

Aplan: Just old work clothes. Just old pants and a shirt.

Swent: No safety gear?

Aplan: We didn't wear hard hats in those days. You would usually wear safety glasses but not always. Safety came in in the sixties. Before that--though I would say the plant was so well organized that there weren't many safety problems. I don't know of any injury during the time I was there. I think it's a little bit like--you don't find car accidents on a narrow mountain road, but you find them on the Interstate. People were naturally careful.

Swent: Yes, you were very careful.

Aplan: You were careful and they would take you aside and speak to you if you did something unsafe. They were very proud of their safety record.

Swent: What kind of orientation did you get to the job? Were you given any safety instruction?

Aplan: I showed up and Claude said to go and see Sven. [laughs]

Swent: And that was that.

Aplan: That's right. And, "Here's what we're going to do. Grab this." But everything was well organized and so it went very smoothly and you learned very quickly. The shift boss would speak to you if you did anything out of line. And on some--particularly when it got to the cyanide plant, you didn't have to work all the time. In the South Mill I was working every minute of the day; there was always something to be done, but in the cyanide plants, as sluicer, you had to wait for the vat to fill, and so you've got some dead time. I would talk to the operators and find out what kind of titrations they used for cyanide and for

alkalinity. And then when Frank or Claude came by, I would talk to them and ask about the assays and operation details. It was a very good family relationship in the mills, and as you know, Lead was a very close town.

Swent: Yes. Where did you live?

Aplan: I lived at a boarding house in the next street down from the main drag, below where the Mining Museum is now.

Swent: You roomed and boarded at the same place?

Aplan: Yes, and the second year I lived in a brick apartment building on the main drag. The building is gone now. They claimed that there were all outside apartments, but it was about two feet over to the wall of the next apartment section and you could see the sun for about five minutes a day, near noon, [laughs] but I was rarely there to see the sun. My roommate from the School of Mines was working for the National Guard in Lead so there were two of us living there, batching, and we would argue sometimes over who had to cook the dinner. But we soon found that if you filled up the glasses to the second red rung with scotch, the arguments on who had to do the cooking decreased. [laughter]

Swent: Oh, you were doing your own cooking, too.

Aplan: Oh, yes, and I would pack a few sandwiches for lunch, too. In the boarding house they packed them for you because there were a lot of people that worked at the Bald Mountain Mine also living at that boarding house.

As a relief operator I filled in for people on vacation. Of course, the regular operators took their vacations when scheduled on graveyard or swing shift. If I would be on graveyard shift, I would often have trouble sleeping so I decided to use a few beers to help me sleep. Well, that didn't work too well because the beers went through my system very quickly [laughs] and so I was up frequently. I finally just put up with the heat and the noise. At night of course everything's nice and cool, but in the daytime it got pretty hot.

Swent: Was it two weeks on one shift?

Aplan: They changed shifts every two weeks, but they had an unusual system; you worked a forty-two-hour week. Sunday, Monday, and Tuesday you worked four six-hour shifts: day, afternoon, and graveyard, with a true swing shift, from seven p.m. to one a.m. The last four days of the week you worked eight-hour shifts: graveyard, night, and day, with one day off.

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Swent: You were explaining about the short change.

Aplan: The regular day, afternoon, or graveyard shifts were okay, but the operators didn't like the swing shift, because they had the short change: say, after the graveyard shift you had to come out on the following afternoon shift, so you just had eight hours there; by the time you got changed and everything you had seven or seven and a half. But I liked that because in addition to a day shift I had a day off. I think I had day shift on Friday and my day off on Saturday, so I didn't need to show up until seven o'clock Sunday evening, so I essentially got two days off. And I was single and had a car and so forth so I was attracted to that.

"Junior Year with Uncle Sam", 1942 to 1946; Combat in Europe

Aplan: This was World War II, and I had a very long junior year at the School of Mines: i.e., almost four years out for Uncle Sam. [laughs] I enlisted on November 2, 1942. I hitchhiked from Rapid City to Fort Meade. I tried to enlist at the end of October, 1942, but Fort Meade, home of the Fourth Calvary, was still an old army post and the end of the month was pay day and on pay day everything shut down, so I hitchhiked up to Sturgis, again on November 2 , walked out to Fort Meade, and enlisted.

Swent: You could have been deferred, couldn't you?

Aplan: In those days you wanted to be in the service, unlike the plain and fancy draft-dodging of later years. They weren't drafting eighteen- and nineteen-year-olds at that time but most young men wanted to enlist. I didn't wait--I wouldn't have been drafted for several months, but anyway I went out of my way to enlist.

I finished the term at School of Mines--they allowed me to do that--and then I was sent to Fort Snelling, Minnesota, for classification, and they shipped me to the Infantry Replacement Training Center at Camp Roberts, California. It was near Paso Robles and the San Miguel mission and the Hunter-Liggett military reservation, that area. It would hit 125 degrees Fahrenheit in the shade and there wasn't any shade. I was supposed to have thirteen weeks of basic infantry training, only it lasted over five months. Well, like the army [laughs] things don't move--but I received some excellent training.

Aplan: Then there was a boondoggle program called Army Specialized Training Program [ASTP]--it was supposed to train engineers and language students for the military. The concept was good. I think the basic impetus, though, was to keep the colleges open. They had an ASTP at School of Mines in Rapid City, but other people went to that one; I was sent to Syracuse. It was quite good. There were 3,800 G.I.s there, both Army Air Corps people and ASTP engineering students and then a small language program and then about 300 4-Fs [deferred category] plus several thousand women--it was co-ed--so that was a pretty good deal. I took the mechanical engineering program.

I went to Syracuse in November of '43 and less than four months later, on the first

of March, the army made a discovery: they had utterly, totally, and completely underestimated the amount of infantry they needed: not just a little, not just 2 percent--but massively! And they had been taking casualties--

Swent: This was March of 1944?

Aplan: Yes. The infantry had been taking massive casualties at Guadalcanal and in North Africa, and they couldn't replace them. They had several infantry replacement training centers such as at Camp Roberts that I went to and they also had them in Florida and Georgia and so forth, but they just couldn't turn out infantry replacements fast enough, so they took the Stateside divisions--infantry, airborne, and armor-- there were probably about fifty of them, and they began to pirate them for replacements. New divisions had been put together of draftees from 1941 to 1943, trained, and stripped for replacements because the replacement training centers weren't turning out enough.

To give you a frame of reference of this, Eisenhower in his book *Crusade in Europe* points out that in the army 71 percent of the total casualties came out of the infantry, so to fill the pirated divisions up to full strength, they came up with a slick thing: "We've got all these kids sitting in college," so they cleaned 138,000 of us out overnight, plus they got some aviation cadets, as well as some from a few other branches such as tank destroyers and got replacements from some of those. We then went to fill up these fifty divisions or so that were missing people because they'd been pirated. Now this pirating could be rather substantial. A division has 15,000 men, and 9,000 are in infantry. I went into the 69th Infantry Division, which had originally been formed in 1943. By the time it reached combat in 1945, the 69th had been pirated for 26,000 men out of an original strength of 15,000. In the division, these men mainly came out from the 9,000 infantrymen. But what they would do is replace the men, they would then pirate them, fill up the division, give a little more training, and then pirate them again. That just kept going on and on and on. The net result of this, though, is it raised the intelligence of the infantry massively.

You needed a score on the general classification test of 110 to be an officer, but you needed 125 to get into ASTP, [laughs] so here, suddenly, all these students came to these infantry units--

Swent: All of officer quality.

Aplan: So I was sent to Camp Shelby, Mississippi, where I joined the Company I, 272nd Infantry of the 69th Infantry Division. As I mentioned, the division has 15,000 men: 9,000 are in three infantry regiments of about 3,000 men each and then the division artillery men, the quarter masters, the engineers, the medics and so forth make up the rest of the division.

Company I was a rifle company. In the infantry regiment there are nine rifle companies; these are the workhorses. They have three rifle platoons of about forty men, and they have one weapons platoon. The weapons platoon has three 60-millimeter mortars and two light machine guns. I was a little bigger than most so I ended up in the

mortar section. The problem there is you either carried the 42-pound mortar or you carried thirty-six pounds of ammunition, that was the choice. [laughs] Well, I ended up as a mortar gunner carrying the 42-pound mortar. I also ended up being probably the most basic-trained soldier in the U.S. Army.

They kept losing the records and they would say, "Go out to the rifle range again."

"I've already done the rifle range--I did it three times at Camp Roberts."

But, "We haven't any records," so then you had to go out and do that. "You have to do the village fighting course again."

"Well, I already did the village fighting course four times."

"Go out and do it again." [laughs]

And on and on like that. I ended up in the mortar section. The mortar section has a section staff sergeant, three mortar squads each with a buck sergeant leader, a gunner, an assistant gunner, and two or three ammo bearers. I spent a good deal of my time with Company I as the gunner. The mortar weighs forty-two pounds and I carried that thing in the States and from the Siegfried Line to the Elbe [River] plus all my other personal belongings: a knapsack, poncho, mess kit and eating utensils, several K or C rations, canteen, first aid kit, entrenching shovel, trench knife with ¼ pound block of TNT for rapid hole digging, gas mask, mortar sight, Colt .45 and pouch with extra ammo clips, grenades, pen, pencil, paper in waxed paper pouch, address book, and a small prayer book. It was winter so I wore two field jackets, the new style over the old, and early on, a wool overcoat. Bedrolls were carried by the company kitchen truck but you'd often not get one. The troops hated the gas masks and would lose them at any opportunity. They kept re-issuing those damn gas masks; maybe the army thought the Germans would resort to gas, but we felt we were already carrying enough stuff and gas masks were expendable.

The interesting thing about infantry is we were all kids and I guess we felt we were going to live forever. I don't ever remember a bull session in which we sat down and said we're in a high risk profession. It never crossed our mind that you could get killed. Well, we had a rude awakening on that.

I was shipped to England in November and the troop ship was an old luxury liner, originally built in Germany, called the *John Ericksson*; it was the sister ship of the *Gripsholm*, which was used to repatriate State Department people during World War II. It was a good ship, but in November the Atlantic was moving in every which direction and I was so seasick they could have shot me and I would have said, "Thank you." Oh, I was deathly sick.

We landed in Southampton. We stayed in England a few weeks and then we went to the Continent. I got to the Continent in January and we went to the Siegfried Line where we replaced the 99th and what was left of the 106th Division. The 106th had been

hit by Von Runstedt about the third day they were in action. It was a green division and they were hit by two Panzer armies--not two Panzer divisions, two Panzer armies--and they lost two regiments, though fortunately most of the men turned up as POWs [prisoners of war] after the war. We replaced what was left of that division, the 424th Infantry Regiment, as well as the 99th Division. The 99th had been badly mauled by the Germans, but they had been in action about a month, so they were able to survive better. So we replaced those two divisions.

An interesting thing comes up here. Of course I knew none of this at the time, but we entered the Siegfried Line near a Belgian town called Krinkelt, about thirty miles south of Aachen. Now I knew that my mother's grandmother, who arrived in the U.S. about 1850, came from near Aachen--when they came to this country it was Aix-la-Chapelle--but anyway, Aachen, Germany. I didn't know any more than that, but a few years ago I got a letter from my sister, "Please send us your birth date, your children's and grandchildren's names, their birth dates, and all that stuff." Later I got a letter from a woman in Wyoming; she said, "We've done the Girgen family history and you can buy a copy." I'd never heard of Girgen family, so I started checking up and my grandmother Fischer's grandmother was a Girgen. So I bought the book and looked in there and guess where the Girgen family home town was--Krinkelt.

Swent: For heaven's sake.

Aplan: This little farm town had been well beaten up because the armies had moved back and forth through there several times. It was near the Losheim Gap, so the Germans had come through there in 1940, then they were chased out again in August of '44, then they came back in December during the Battle of the Bulge, then they were chased out again, so Krinkelt wasn't in very good shape. But it was interesting that I would be there.

Swent: Well, yes.

Aplan: We crossed the Rhine at Remagen. The bridge had just gone down, so we used assault boats to get across. We then went down the Rhine and up the Lahn River a ways and then north into Kassel.

The 69th and 80th Divisions took Kassel, and I marched thirty miles that day to get there carrying that 42-pound mortar. Then we went east toward Leipzig. And an infantry division can't carry itself, so each corps was stripped down to two infantry and one armored division. I was in the Fifth Corps of the First Army. The V Corps had the 2nd and 69th Infantry Divisions and the 9th Armored. The 9th Armored had taken the Ludendorff Bridge at Remagen. Everyone else was left behind to attack the Ruhr pocket of Germans. And the rest of us moved east from Kassel.

We rode wherever we could ride. We were riding on tanks, we were riding on tank destroyers, we were riding on ack-ack [anti-aircraft] gun carriages, et cetera; my company rode sitting on top of ammunition for the artillery. We would go east until we ran into some Germans, then we would get off and clear the Germans out and then we would get

back on the truck. These episodes would last from a few hours to a few days. We were going down one side of the road and the Third Army troops were going down the other side. We went over to Leipzig and the 2nd and 69th divisions took Leipzig. Then outside of Leipzig a few weeks later--I think, on the twenty-sixth of April, 1945, the 69th was the first division to meet the Russians. I wasn't in the unit that did that, but I got to see the Russians *au naturel*. This was the 58th Ukrainian Guards Division.

[Added later: Two things impressed me about the Russians. The first night we met them it was raining and they came marching along singing. Had it been the other way around, we'd have been sullen and bitching with no singing, not unlike Willie and Joe in a Bill Mauldin cartoon. Secondly, they were unfamiliar with wrist watches, mechanical pencils, or fountain pens. They quickly liberated these from the Germans and some Russian soldiers would have their arms filled with wrist watches and their pockets filled with pens and pencils, not all of which worked. After the war, the Russians would pay a hefty price for a Mickey Mouse watch!]

After the war, the army came out with a point system which rated you for discharge, selection for the army of occupation, or being sent to the Pacific. In some cases they sent the whole division, and in some cases they just sent individual replacements. The point system was fair and unfair, and the unfair part--it was rigged against the combat infantrymen and favored some rear-echelon troops. I won't go into the details--the combat infantrymen didn't get quite the shake many of us thought that we should get, so I was one of the "lucky" ones selected to go to fight another war in the Pacific.

Swent: Where were you then--it was May--

Aplan: When the war was ended I was over by the Elbe. Then we moved back into Germany into what was to be the American zone. We gave up all that territory to the Russians, because they had made an arrangement with them to give them this much. And I might add, we could have walked to Berlin and beat the Russians. There was a political decision made for us not to go in. We weren't in the easiest position to get to Berlin, but there were a lot of U.S. units that could have gone into Berlin easily. And we wouldn't have taken the casualties the Russians did because the Germans knew the game was over but with the Russians they were going to fight to the last man, so the Russians took a lot of casualties to get into Berlin.

Swent: These arrangements, the political arrangements that had been made--were you aware of them at the time?

Aplan: We were aware that we were to move back; that's it. But I have since studied a lot of World War II history. Of course, you know, they told me to go here and I did that, and now, "Go there"--and I didn't know what was going on, but as you read the books you begin to understand why things were done the way they were. It sounded crazy at the time; the whole thing sounded crazy to me, the whole military, but then I began to understand that the army had 135,000 people in the 1930s and expanded to ten million. And when you start contemplating that, it was truly amazing what was done.

Okay. I was at a replacement depot, a "repple depple", in Namur, Belgium, en route to the Pacific. The Germans almost got there in the Battle of the Bulge--they were within ten miles, I think, before they were finally pushed back. In August, 1945, my orders were written. I was to go to the States, we were just waiting for a boat to come into Antwerp. I was to have a month leave in the States. They took all our clothes away from us, you know, except what we had on. And then I was supposed to report to P.O.R. [Port of Replacement] San Francisco. Truman then dropped the atom bomb. So you don't hear me complaining about the atom bomb because it saved my life. Surviving infantry action in two wars is a low probability situation.

Then what do you do with all these soldiers? They had three and a half million people in Europe, and they had no way of taking them home at one time, and so at the repple depple, they took all of us whose name began with A and B and sent us to Rheims, France. Now when I found that out I was very happy because my father was stationed in Rheims. [laughs] Just after the war I had visited Rheims once. As a matter of fact, I went AWOL [absent without leave] with my company commander. My company commander said, "You're on shipping, I can't give you a pass, but you can come with me if you want to." [laughs] Now I subsequently learned about fake passes but I was too dumb at that time. But anyway, I went and found my father in Rheims.

Swent: He was in the army, also, you said?

Aplan: Yes, he was a quartermaster officer, and we were together for a few weeks and then I was transferred to another outfit about twenty miles away, so I got to see him. Then he went home shortly after that. He had enough points on the point system to go home and I didn't.

When I first got to Rheims, I was in a de-gunned artillery unit that was guarding the French and the Poles who were guarding the German prisoners. The black marketing going on was out of this world and so they had these big depots of shirts and helmets and jeeps and whatever--just acres of them! Which we were supposedly guarding. Well, they were black marketing whole train loads out of the depots. You know, black marketing out of this world.

But anyway, then I was fortunately transferred to U.S. Foreign Claims service. This was under the Judge Advocate's department. If a G.I. stole a bicycle or beat up a Frenchman or damaged something, then we would pay claims. I first started out investigating claims and then they said, "You're a clerk." Well, I do one-finger typing, so I was a clerk. Later I was the chief clerk which was essentially a financial conversion person with the Foreign Claims Commission in Paris--which was one of the most difficult military duties I've ever had.

Swent: I'm sure. [laughter]

Aplan: I had a jeep at my disposal--but anyway, when I first got to Rheims I sulked because I said here are these rear echelon guys going home and I was in combat and I'm stuck. Well,

after sulking a while I said, "Well, you know I'm not going to get home any sooner," so I went and with a jeep at my disposal I saw all the chateaus, the World War I battlefields, cathedrals, everything I could in northern France. And then when I was in Paris I kept that up and kept going all over that part of France. Also I went skiing in Chamonix and I went on pass to visit Switzerland and finally I got a transfer to Paris.

Swent: Not all bad.

Aplan: Not at all bad. I was in no hurry to go home because I wasn't going back to school until September of 1946 and this would be roughly a year before, so I volunteered to stay over in Europe. I could have gone home about the end of the year but I stayed over and came back in June of '46.

Let's see if I've forgotten anything. I ended up as a technical sergeant--it's now called sergeant first class--5-striper, three up, two down--and I hold the combat infantryman's badge and the bronze star.

Swent: What did you get the bronze star for?

Aplan: Bronze star was given for two reasons: it was given for valor and it was given for meritorious service and I got one of those on the cheap: the meritorious service one [laughs] rather than the valor one.

Swent: It is very impressive to have; I'm sure you've understated what you went through.

Aplan: Okay, let's go eat lunch.

[tape interruption]

II MONTANA SCHOOL OF MINES, 1948 TO 1950

Research on Separation of Galena from Sphalerite

Aplan: This will cover my time at the Montana School of Mines--the period from 1948-50.

Swent: You got out of the army in--

Aplan: I got out of the army in '46 and spent '46 to '48 at South Dakota School of Mines finishing up my B.S. in Metallurgical Engineering.

Swent: How did you happen to go to Montana?

Aplan: Well, I kind of was interested in taking a master's degree and I wrote around to several schools. The best acceptance letter I got was from Don McGlashan. He was a very enthusiastic guy. He was head of the mineral dressing program at Montana School of Mines--now called Montana Tech of the University of Montana--and he offered me a graduate assistantship.

Swent: Was there no graduate program at Rapid City?

Aplan: A very small one had existed under Bancroft Gore, but with two new faculty, they hadn't yet restarted it. I had written to several schools and there weren't many master's programs in mineral processing actually in the country at this time. Very little graduate work in the minerals field anyway. McGlashan also offered me a job as a graduate assistant.

Donald W. McGlashan had a B.S. from Idaho, an M.S. from Montana School of Mines under Tony Gaudin, and then had started his Ph.D. at Penn State, and when the war caught him, he was a reserve officer and they called him up and that ended his Ph.D. career. Gaudin had left Montana Tech in 1939 and was replaced by S.R.B. Cooke, later to be at the University of Minnesota. Cooke was leaving Butte in 1946 and so McGlashan came in and took over mineral processing at that time. He was a very enthusiastic guy, forward thinking, and had developed a strong graduate program with about six graduate

students. It was a very dynamic go, go, go situation. About half of the students that were there at the time I was subsequently got a doctorate from some other school. As I mentioned I was there for two years. During the second year Doug Fuerstenau came in from South Dakota School of Mines so we were together.

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Swent: You had been together at Rapid City in South Dakota School of Mines?

Aplan: At South Dakota School of Mines and so I knew him since 1946. It's kind of interesting--of the group--the Montana School of Mines had about maybe 370 students at the time. Today they're up to about 2,500. And interestingly enough, three of us at the school at that time: Bob Kupfer, also one of McGlashan's students, and Jean Hardesty in geology--all three of us had been in the 69th Infantry Division.

Swent: Had you known each other?

Aplan: No, you know, out of 15,000 men in an infantry division, the chance of knowing someone personally was very low.

I worked on a research project involving the separation of galena from sphalerite. Anaconda was using a very unusual method. The typical method is to float galena while keeping the sphalerite depressed, then add copper sulfate to activate the sphalerite so it thinks it's a copper mineral and floats. At Anaconda they used a different process. They made a bulk concentration of lead and zinc; they then heated the pulp and added some cyanide and zinc sulfate depressants and floated the galena from the sphalerite. My job was to find out fundamentally what happens to galena and sphalerite when you raise the temperature in the pulp.

Swent: Was this something that Anaconda had asked to be done?

Aplan: No, this was just to develop a fundamental understanding of this unique process; because what Anaconda did was unusual; there was no information as to how it worked, so that's what we were looking at.

Swent: You were analyzing it to find out why it worked.

Aplan: Yes. So this continued some work done by Bob Barson who later was assistant director of research for Armour Chemical. Armour Chemical at that time was a major flotation reagent manufacturer.

There were an awful lot of projects going on because McGlashan thought broadly. He was supervising ion exchange of acid mine drainage with sawdust before ion exchange was used commercially in the mining industry by looking at removing lead, zinc, and silver from Coeur d'Alene mine waters. They have been busy cleaning up in the Coeur d'Alenes ever since and right now it's a major Superfund site. He had a project on

flotation of base metal oxides, particularly the copper and lead minerals. This was work done by John Doherty who later got his Ph.D. from Utah. Then when Doug Fuerstenau came in, he took over part of that project and did some outstanding work on the use of chelation agents to float malachite and azurite. Another student, Walter Finnegan, was working on sulfidization of cerrusite, a lead carbonate, while Bill Joyce was working on the recovery of unleached sphalerite from the leaching of zinc concentrate.

Anaconda had zinc plants in both Anaconda and Great Falls, so I guess the watch words of McGlashan's operation were practical, dynamic, good science. It was an interesting time. Will Guay also came in as a McGlashan graduate student my second year. During this period I got to know Ted Jordan well. He was a freshman in metallurgy and worked part time in the building. Many years later Ted became head of the metallurgy department at Butte.

A Summer Job at Day Mines as a Surveyor, 1949

Aplan: During the summer of 1949 I got a job by mail--that is, I wrote over and asked for it--at the Hecla Mine of Hecla Mining Company in Wallace, Idaho, in the Coeur d'Alenes. Unfortunately, just as I got there the price of zinc had dropped from 17 cents to 9 ¼ cents overnight.

Swent: Oh!

Aplan: They shut down the mine. No job. I felt like I was at 10,000 feet with no engine and no wings. So I rustled around and found a job with Day Mines, Inc.

Swent: Were you using the G.I. Bill to go to college? [Serviceman's Readjustment Act of 1944]

Aplan: Yes, yes.

And the Day Mines was an interesting operation, with several operating mines and a lot of mining claims. I was hired to do surveying, and I remember complaining a lot at Rapid City about taking surveying, but it turned out doing that doing that surveying wasn't too bad.

Swent: You were glad to have it.

Aplan: This was both underground and surface surveying. The head of Day Mines was Henry Day. The Day family was very prominent in the Coeur d'Alenes, and one of their old mines up Burke Canyon was called the Hercules. You can currently buy a book called *The Days of the Hercules*. Henry Day had maintained the family interest in mining and had gone out and bought every claim that he could find anywhere around Wallace. These were both patented claims and unpatented claims. As in most cases in old mining

districts, the claims overlapped, and so the idea was to rationalize the whole thing by setting them out with common end and sidelines.

It was a tough job because the mountains in the Coeur d'Alenes are quite steep. You'd swear they're 45 degrees as you're going up; they're probably only about 35, but they're especially steep and you have to drag a brush hook up there along with a transit and tape [laughs] in order to get the job done.

Swent: And in all kinds of weather?

Aplan: Oh, yes. I worked with Terry Davis, who had graduated from Michigan Tech at Houghton, Michigan. Day had four or five operating mines and several had mills. An important pair of mines was the Sherman-Hercules, which had a common entry adit which was split inside the mountain. The Sherman was an upside-down mine which went up, while the Hercules had been sunk as a conventional mine. It dated from the last century, but it was mostly shut down in my era. Inside of the Hercules was a winze which used a flat-belt hoist. I had never seen a flat-belt hoist before. Instead of using a cable with circular cross-section, a woven webbed belt about three or four inches wide was wound on the hoisting drum.

The Sherman Mine, as I said, went in from the adit and after the split there were a series of raises so they were almost mining the tree root hairs, in some cases. You could go up near the surface and pick out the most beautiful pyromorphite--a lead mineral that had taken up vanadium and so it had these beautiful green crystals. I still have a small piece. If I had had a pick-up truck loaded with that stuff, it would be worth a fortune today. Unfortunately we ground it all up and sent it to the mill. I think this was the last major sulfidizing mill operated in the United States. The process was written up in *Mining World* in the early 1950s.

Sulfidizing was a technique to take, say, a lead carbonate or a copper carbonate or a zinc carbonate and put a sulfur coating on it so that it acted like a sulfide. The flotation collecting reagents thought it was sulfide mineral and floated it as if it were a sulfide mineral, so it could be floated from the gangue.

Swent: Why did they quit doing that?

Aplan: There are not enough of those types of ores any more. They're mainly into sulfides now. There are other reasons, too. The tailings from sulfidization are quite high in metal values so today with ore grades quite low, a high metal tailings content means that the overall recovery would be very low, so it's not worth it.

The Sherman-Hercules boarding house where I first stayed was the former fire house at Burke. Now Burke Canyon is a very narrow canyon. As I first drove into Burke to go to the boarding house, whom do I meet coming down the road but a Union Pacific Railroad train. The canyon is so narrow that the creek, the road, and the railroad all co-occupy the same space. To get to some of the mines just above Burke, the train went

through the Star Mine boarding house, so there was a big hole in the boarding house. The train went through the boarding house! [laughter] The canyon was so narrow that in older days the merchants had to lift up their awnings when the train came by. [laughs]

At that time the only two mines that were running in Burke were Hecla's Star Mine and Day's Sherman. The Dayrock Mine was further down the canyon. In the evening I used to go and have a beer at the Stein Club in Wallace, and as I was there one evening in walked Doug Fuerstenau and Royal West from South Dakota School of Mines. I didn't know they were within 1,500 miles of the place! They were working for Bunker Hill and Sullivan over in Kellogg; Doug in the smelter and Royal in the mine.

I had a car, so Doug and I visited every mining and metallurgical plant we could find in the area. Bunker Hill had a mill, a lead smelter, and a zinc plant. Doug was working in the lead smelter. ASARCO had the Morning Mill at Mullen. Around the corner from Bunker, up Pine Creek, was the Sidney Mine. And that's kind of interesting. The superintendent there was Archie McKinley. There were three McKinley brothers--one--I think Frank--was at Bunker Hill, and Harold ran Union Carbide's Pine Creek Mine at Bishop. They were all out of the University of Idaho. Then we also visited Hecla's Star mill at Burke and the Sunshine mill which was between Wallace and Kellogg. We also visited a couple of smaller operations, so it was a very good education in metals processing to see how those flow sheets worked. All of those people would welcome visitors. You know, we weren't considered just a pain once they saw that we were truly interested in their process.

Then it turned out that Doug was going to go to graduate school at the Montana School of Mines, so when we finished our summer jobs, I drove us back to South Dakota. After a week or so at my home in Ft. Pierre, I drove back to Butte, picking Doug up in Rapid City. At that time I met Maurie [Maurice] Fuerstenau, Doug's younger brother, who was in high school at that time.

Butte, a Dynamic Town; Good Live Music

Aplan: Butte was a good town, it was a dynamic town, it was a fascinating town. Anaconda was running nineteen mine shafts: two for manganese, five for lead-zinc, and the rest of them—that would be twelve--for copper. Everything was going in that town. Metal prices were reasonably good even though the zinc price had suddenly decreased. The manganese mine--they had two manganese mines--it was interesting; the mineral was rhodochrosite and in the stopes I've seen beautiful pink rhodochrosite maybe six feet wide which was dug out, ground up, sent in the kiln and put into a submerged arc furnace to make ferromanganese. Again, if I had a pick-up load of this for the mineral collectors, [laughs] today I would be doing well.

So Butte was very laid back--kind of a laissez-faire mining town. To give you an

idea, the first hour in Butte we saw a cop playing illegal slot machines on duty, [laughter] so their approach to gambling was like at Deadwood pre-1950. It was against the law but no one bothered to enforce the law.

The temperature would get 35 to 40 degrees below zero there in the wintertime, and I always walked from the school to downtown. You know, you just put on a heavy coat, a scarf, gloves and ear muffs and walk downtown. The school was probably three quarters of a mile from the downtown. At Christmas time in 1948 I went home to South Dakota over vacation. Coming back to Butte on the bus the first of the year, I was among the last people to leave the Black Hills before the terrible blizzard of 1949 really hit and isolated western South Dakota for several days. Only a bus or a truck could have made it through the drifts that were building up. The bus outraced the blizzard to Billings but Montana was still very cold. Well, anyway, when I got off the bus in Butte, the thought that came to my mind was that if someone had blindfolded me and said, "Where are you?" I would have said Butte. [laughs] It was cold, it was crisp, and it was clear.

When I walked downtown on a cold winter's evening, I sometimes needed a refreshment, so I used to stop at the Bronx Bar on Park Street. Just to show you that kind of laissez-faire attitude--you would see the cop on duty, he would stop in, get a shot of anti-freeze, and then go back out onto the beat. [laughter]

Swent: Where were you living?

Aplan: I was living in the student dormitory on campus.

Butte was a very lively town. In the first place Anaconda was paying good money in the mines. Most of the miners were on contract so if they worked hard they were paid well. There was a lot of gambling in Butte, so in effect the money from the gambling was used by the restaurants to subsidize food and live entertainment. There was a famous restaurant out in Meaderville run by Teddy Traparish. It was later swallowed up by the Berkeley Pit. There was a separate town out there at the time. When I first got there steak was a dollar fifty. And a <u>good</u> steak. Since I didn't gamble, I enjoyed the subsidized steak.

In 1949, the state decided to shut down some of the gambling, which was kind of a fake. They first came in and raided Butte, but Butte handled the situation this way: it was legal to have gambling in private clubs, so over the slot machine they would put "Mary's Club, members only." [laughter] And you paid your dues by standing in front of the machine and pulling the lever. Probably about 1952 a new attorney general decided to stop all gambling in Montana. I was over in Seattle at this time, when suddenly the slot machines disappeared in Montana. In Missoula where the slots had disappeared, they were accidentally found in a building rented from the county. [laughter]

Anyway, they had a lot of live music in Butte because there was money in town, and secondly, if you leave Minneapolis--and in those days everything was by train and there were three railroads connecting Minneapolis and the West Coast--where is there a

city between Minneapolis and Spokane or Seattle? Butte's the only significant place. Billings was much smaller and didn't have much money. So Butte was the place, and you could see a lot of small bands, typically three- or four-piece bands, playing there. One of the favorites Doug and I used to go to was called the C.O.D. Club. It was in kind of a rough area but they had a wonderful Dixieland band headed by a guy by the name of Jake Flores, who played trombone, out of Los Angeles.

Out in Meaderville they also had several country-western bands, but on a weekend there were probably half a dozen small bands, playing in greater Butte. There was a fairly high Italian population in Butte--the Walkerville sub-group of Butte was mainly Italian--and of course Italians are big for music and so there were a lot of people who had other jobs that were good musicians and they would work on a weekend. There was a lot of good live music in town and that was a wonderful experience.

We had a small South Dakota School of Mines alumni association over there. Doug Fuerstenau and myself and Kurt Graverson, who was an assistant professor in metallurgy, had all been at the South Dakota School of Mines. Scotty Burrill was working in the smelter over in Anaconda. Scotty later worked for Kennecott at Nevada and at Ray and ended his career at ASARCO's Mission Mine just south of Tucson. Lauren Henton and Bob Hamilton, both of whom graduated in mining at SDSMT, worked underground for Anaconda at Butte. So there were six of us and we would get together out at Teddy Traparish's supper club for the cheap steak and reminiscing. [laughter]

I first became interested in jazz music over in the Coeur d'Alenes when one of the guys working over there in the summer had some jazz records. I was kind of impressed, so I started listening to them and I used to go to the Record Mart in Butte. There was a girl there by the name of Margueritte Kane. She was a whiz at finding exotic jazz records that were put out by small companies; she would track them down for me. She later married classmate Chuck Arentzen. Chuck had been a young sailor in the Philippines in December, 1941, and spent the war as a "guest" of the Japanese working in their coal mines. After graduation in 1950, he worked for Anaconda and other companies in the Tucson area, where they now live.

All in all, I would say I had a wonderful educational experience in Butte. There was a separate mineral dressing department--a one-man department--plus a fairly strong three-man met department headed by Jack Speilman who was later the engineering dean at Washington State.

To give you the flavor of what that met group was like at Butte, in the thirties they had four men involved: Curtis Wilson, who was later head of the Missouri School of Mines at Rolla, Missouri; Tony Gaudin, who later went to MIT; Worth Kriegel, who later headed the ceramic department of N.C. State; and E.A. Perretti, who later was in Notre Dame's met department. So all four of these people were exceptional, and I know of at least four text and reference books they wrote at Butte. The quality of the program was also high in my era and continues to do a good job to this day.

To show you the strength of the program at Butte, there had been eight graduates of that school, incidentally all of them from metallurgy or mineral processing, who are or were before they died members of the National Academy of Engineering, including one, Tony Gaudin, who was a founding member of the academy.

I minored in geology for my M.S. at Butte. I had minored in geology at South Dakota; an unofficial minor because they didn't have a formal minor. I did a formal minor in geology at Butte and then later at MIT I did another minor in geology. Our commencement speaker in 1950 was Don McLaughlin of Homestake and Cerro de Pasco fame.

[Added by Frank Aplan during his review of the draft transcript:

Another excellent educational feature was the proximity of the extensive operations of the Anaconda Copper Mining Company. I had the opportunity to visit mines in Butte and the reduction plants in Anaconda, MT were only 25 miles away. There we visited the copper, lead-zinc, and manganese crushing, grinding, and flotation mills, the copper smelter, manganese furnacing, zinc leaching and electrolysis, and the phosphate fertilizer operations. During vacation Doug and I took our own field trip to Helena to see the ASARCO lead smelting and zinc slag fuming operations. Then on to Great Falls to see Anaconda's copper refinery and zinc leaching and electrolysis plants and to visit my 1941 SDSMT classmate Larry Ingvalson who was now plant manager. We stopped at the Mike Horse Mine, run by recent Montana School of Mines graduate Koehler Stout, on the way back to Butte. There was a short-lived pyrolusite manganese concentrator run by Montana Mines graduate Stan Huckaba in an old building down by the Milwaukee Railroad depot. Visiting there about 1948 or so I had the pleasure of meeting Mr. Griswold of the Sheridan-Griswold cyanide depression patent for sulfides.]

Now, to kind of summarize--I have many fond memories of my time at Butte. I learned a lot, worked hard, still had some fun, and made many good friends. I owe a special debt of gratitude to Don McGlashan--he taught me how to think about a problem, he taught me how to conduct research, and he instilled in me the thrill of research and research findings. I have passed through Butte several times over the past 50 years. The city has gone through several cycles of boom and bust. Later, I was in Butte in 1993 when I was consulting on an environmental problem and got to renew my acquaintance with Ted Jordan, who was an undergraduate in my era and later became Met. Department head. . And Butte has come back--kind of interesting. I've been back twice in the last seven years and the place still gives me a thrill. I look at the fifteen or so abandoned headframes favorably. The mining museum has done a terrific job of presenting Butte's mining history, environmental cleanup continues, and there is a lot of optimism in the town. But people look at it and see all the hillsides dug up as an environmental nightmare, but to me it is a true slice of American history. I always come away with many fond memories. My last visit to Butte was in 1999 when I was named as distinguished alumnus of Montana Tech.

Swent: Yes, it's interesting the different reactions that people have to Butte. They point it out as an example of such a disaster and yet most people who have lived there talk about what a

wonderful place it was, what fun they had.

Aplan: I thought it was a wonderful place, but I don't think I would take that weather any more. I've gone soft. Over the years I've noticed that several former Butte residents will gravitate back to the city.

Swent: It's a very vital community.

Aplan: Yes, and it has come back--it has spread out on the flats east of town to the airport and beyond.

Swent: Well, you were young and learning and having fun.

Aplan: Yes, as I said, the learning experience was out of this world.

While at Butte I lived in the dormitory residence hall, while Doug lived just across the hall. Doug was a very skilled cartoonist. Butte Beer used to have newspaper ads and they had a contest that whoever submitted the best cartoon involving Butte Beer won a case of beer. Well, Doug soon saturated the market with his cartoons [laughter] and they're very distinctive so you could always identify the cartoonist. I'll show you some. Then you would start to see the same cartoon style only submitted by someone else. So there was always plenty of beer. [laughs] But Butte Beer didn't taste very good, so I sometimes wondered if that was a prize or not. [laughter] Great Falls had better beer--it had Great Falls Select, which is a better beer. [laughs]

I graduated from Butte with a Master of Science degree.

III WORKING AT CLIMAX MOLYBDENUM COMPANY, 1950-1951, 1953

Working as a Laborer on the "Moly Hill"

Aplan: In May of 1950 I went up onto the Moly Hill, at Climax, Colorado. At that time it was the Climax Molybdenum Company mine. I stayed there until September of 1951 and then I went up there again in the summer of 1953.

Swent: What was that like?

Aplan: The second time or the first?

Swent: Well, both times.

Aplan: I've been very fortunate. I've had very good experiences and I've learned a lot and they were fascinating.

I had seen Climax on the field trip when I was a senior at Rapid City and so I wasn't exactly foreign to the operation they had and I went out of my way to write them. They had no staff jobs available so I took a job as laborer. There were about a dozen of us there who had degrees but were working as laborers, three of us in the mill, the rest in the mine.

This was during the Harry Truman good times. Politicians love to tell you how good the times were--well, they were so good in 1950 there were no jobs until the Korean War started up in late June, 1950. But in May, early June, there weren't any jobs. I could have had a job surveying on the Oahe Dam construction in South Dakota but I didn't want to do that; I would rather work in a mill.

Swent: What were you paid?

Aplan: Oh, I was originally paid hourly and this ran about 200 bucks a month. After a few months I was put on staff. I was test engineer, I was water plant foreman, I worked in the chem lab, and I worked as metallurgical accountant. Lou Cope, a graduate of the Texas

College of Mines, now UTEP, was put on the staff at the same time and went into plant operations.

I was trained, incidentally, in metallurgical accounting by a woman by the name of Dixie Crismer who later married Frank Windolph. And I still keep in touch with them, although they are long retired. At that time Bob Henderson was general manager; Frank Coolbaugh, the son of the former president of Colorado School of Mines, was general superintendent; Ed Eisenach, who later became a vice president, was mine foreman; Max Dessau was mill superintendent, Frank Windolph--called Bud--was assistant mill superintendent; and Ed Frohling was metallurgist.

Climax is at Fremont Pass at 11,320 feet at the base and it went up from there. They had an entire mining camp there, probably 500 or more people, complete with houses for both staff and workers, though a lot of the workers commuted from Leadville. They had a boarding house, rec hall, hospital, high school, and grade school. A general store and café, not company owned, was near by, just outside the main gate. The high school was interesting--for their school size they would invariably be state basketball champs or one of the top ones. If they brought flatlanders up there at that high altitude it was a pushover. [laughter]

Swent: Of course!

Aplan: The winter of 1950 to '51, by March we had thirty-two feet, as fallen, of snow. We had the Harvard High Altitude Observatory up there so we had official weather station data; that's how I knew it. You would get sometimes five foot at a whack and it would be this fluffy stuff. And then the sun would come out and it would all collapse. But when it fell, you had to tie some kind of red ribbon on the aerial of your car to know where your car was.

They had quite a few snow plows, including a rotary plow, on the property.

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Swent: You had just started to talk about the milling process at Climax.

Aplan: They used a block-caving system underground. We would get boulders up to about two feet in size coming out on the train from the mine in 10-ton Grandby ore cars. This went to the crusher building where it was knocked down to about a half inch, using jaw crushers and Symonds standard and short-head cone crushers. It then went to the mill silos which fed 9x8-foot ball mills with about 450-horsepower motors. They used a very coarse grind. They ended up with about 13 percent plus 35-mesh, which is one of the coarsest grinds in the base metal industry. The reason good recoveries could still be obtained is that molybdenite, MoS_2, is so easy to float that even if only a little molybdenite shows up on the outside of a particle it will float quite easily so the recovery is very high. The reagents were essentially pine oil; vapor oil, which is somewhat similar to kerosene; and a little detergent to emulsify the oil.

So they ground it to 13 percent plus 35-mesh and floated it. They started with roughly 0.35 percent MoS_2--molybdenum disulfide--and they floated about 5 percent of the total tonnage at 6 percent MoS_2 so that at that point they were able to throw away 95 percent of the tonnage and not process it further. This was particularly helpful because the largest single cost in milling is the grinding cost. The Climax grind was substantially coarser than that used to produce flotation feed in most base metal concentrators where the grind is typically minus 65-mesh; 65-mesh is about 2/10 of a millimeter, and we were grinding to about 13 percent plus a half millimeter, some particles as coarse as 1 millimeter, so that's quite a bit coarser. The grinding cost savings over most base metal mills was substantial even though the Climax ore was quite hard. It was a quartz monzonite injected with silica later in geologic time.

Swent: And they were still getting good recovery?

Aplan: Very good. It was about 90 percent. The rougher concentrate, amounting to about 5 percent of the initial feed tonnage was taken to a re-grind plant where we used multiple stages of progressively finer grinding and additional flotation, taking the good stuff all the time in the processing and would end up with, say, 90-92 percent MoS_2. When they got through, cyanide was used in the final flotation stage to depress pyrite and traces of chalcopyrite. Later they developed a market for lubricant-grade molybdenum disulfide. This was achieved by adding more stages of grinding and floating and a "creaming" operation that rejected any remaining locked MoS2/SiO2 particles. They got the concentrate into the high nineties by that process and sold it at a premium over that used for ferro-alloy production.

When I first went to Climax we were milling about 6,000 tons a day, which was one of the reasons the company wasn't hiring staff people. They had a mill with a rated capacity of almost 20,000 tons a day and they were running only about a third of that. The Korean War started, and molybdenum is very necessary in hardening steel and making quality steel, so suddenly the demand for molybdenum went sky-high. We had a big warehouse full of barrels of concentrate that hadn't been sold and they shipped all they had. It took them several months just to get it shipped out since they had so much in storage. And then they cranked up the mill throughput to 18-20,000 tons per day.

We could do this because we had multiple circuits; we had eight lines of grinding and flotation and we were using maybe three of them and suddenly we were using all of them. And in addition, the grinding mills could be fitted with low- or high-speed trunnion gears so they put in the high-speed trunnions.

When moly wasn't selling very well and they wanted a higher recovery, they put in a low-speed gear, giving a grind that was about nothing plus-35 mesh. They got higher recovery, 95 [percent], but when one can sell moly, the idea is to sell moly. And so they put in a high-speed trunion, made a coarser grind, and dropped their recovery to about 90 [percent]. It was a trade-off of recovery and capacity. Now they needed all the moly they could get.

Swent: But if they had the capacity already? They must at previous times have needed that much.

Aplan: Yes, left over from World War II they had the capacity in both mine and mill. In the late 1940s they had been waiting for moly demand to increase and suddenly it did so the stockpiled concentrate was valuable. [laughs] When the Korean War started, they sold a lot of moly.

An Unusual Plant to Recover Trace Minerals

Aplan: The most interesting thing about the Climax milling process was that the moly rougher flotation tailings contained traces of wolframite, an iron-manganese-tungsten mineral, about 0.027 percent; monazite, a cerium, rare-earth phosphate, about the same amount; and a little bit of cassiterite, SnO_2, tin oxide, probably about 0.002 percent. And they worked out a process at the Climax research lab in the old mill building at the Colorado School of Mines campus at Golden. In the late forties Professor A.J. Weinig and Climax lab manager Bob Cuthbertson as well as the local mill staff developed a most unusual plant to recover these trace minerals. Let me describe the plant, basically. Unless you know something about milling, it might not mean much, but for those that do, it was a fascinating plant. [laughter]

They took the flotation tailing and they ran it to a high-weir Akins classifier. The slime overflow went to waste, though later we took the slimes and sent them to a hydrocyclone and recovered some additional coarse material. The sands then went from the classifier to Humphrey spirals. They had 218 or maybe 216 of them--I forget. The spiral concentrate then went to shaking tables and the concentrate from the rougher tables went to a cleaner shaking table. The concentrate from the shaking tables was sent to flotation where the pyrite was floated away--this was all done wet--it then was sent for tramp-iron removal in a Crockett magnetic separator, the material was dried, and sent over an 8-coil Wetherill magnetic separator.

Swent: Eight-coil?

Aplan: Yes, each coil had different ampere-turns with increasing magnet strengths as you went on down the line. Actually there were two separate 4-coil machines, but that's a detail. They separated wolframite, a tungsten mineral, iron-manganese tungsten mineral; monazite, the cerium rare-earth phosphate; black minerals such as rutile; and the tails were quartz, cassiterite, and some pyrite that got by in the flotation process. Now that was run every day every shift and one operator ran that whole thing.

Periodically, depending on how much ore we were running, but maybe several times a month, we would run a flotation plant to remove the monazite from the wolframite. The wolframite was going to go for steel-making, and you don't want

phosphorous in steel. There was phosphorous in the monazite so you had to get the monazite away from the wolframite. Then the monazite was valuable. Rare earths were used as an inoculant in foundries, as an additive. The magnetic separator wasn't perfect, you know, so some minerals got in the wrong places and we had to clean up the products by flotation. From the tails of the monazite flotation, more wolframite was recovered. And then the tails from the magnetic separators contained the cassiterite and we used more gravity separation to recover cassiterite--tin. We were the largest tin source in the United States. It was dinky, but it was still the largest because there wasn't any other. The only other source was Good News Bay up in Alaska but that was shut down at the time.

Now, it gets even more interesting. Remember I said when they took the spiral concentrate and tabled it? The tails from the table contained fluorite and topaz and that went over to a special gravity circuit of more spirals and more shaking tables and then they floated the fluorite away from the topaz. The topaz was used to put in the cement grout used for tile in shower stalls and stuff like that. The topaz grout would take a better polish and stand up better. And fluorite could be sold, mostly for metallurgical purposes.

Swent: So they were really selling everything!

Aplan: So it was a fascinating plant. And even as a laborer I worked in that plant--in fact, I worked as underneath man on the spirals. One should have had rain pay for that because it was just a deluge up in those spirals. But it was an interesting, fascinating operation.

Swent: I'm always interested in what you wore when you were working in each place.

Aplan: Just plain old work clothes.

Swent: Did they issue you anything?

Aplan: No, no.

Swent: Did they provide--

Aplan: No, in those days you never got anything. The only place I've ever known anyone to be issued clothing was at the Homestake refinery because when the clothes got worn out at the Homestake refinery, they burnt them. They were worth more at the end of their useful life than when they were new because of the pick-up of precious metals in the refinery.

Swent: Gold--right. You provided your own boots and--

Aplan: Everything.

Swent: And hard hats?

Aplan: No, no hard hats--

Swent: Not yet.

Aplan: No, and didn't require any safety glasses or safety shoes in those days.

Swent: Gloves?

Aplan: Yes, if you were doing rough stuff. At Homestake on the bull gang you always wore gloves because it was heavy work, but I was mostly doing wet work as a laborer at Climax, so I didn't want any gloves.

Swent: What sort of safety training or precautions were there at Climax?

Aplan: They had a safety engineer, who in my opinion didn't do very much. [laughs] But again, most of the people employed were knowledgeable. The mill had good quality employees. In the mines they had some good, some not so good, but the mill had very high quality people. Leadville had been hit hard economically so Climax supplied jobs for many people living there, so a lot of these people were experienced in mine and mill work. With these good quality people I know of no lost-time mill accidents in the entire time that I was at Climax. People who were raised around mining camps knew how to take care of themselves.

Swent: Did you join a union?

Aplan: When I was a laborer I had to join the union.

Swent: What union was it?

Aplan: It was Climax Molybdenum Workers, a separate union. They had been part of the Mine, Mill, and Smelter Workers. The union had been infiltrated by Communists pretty heavily at that time, and when a union official came out from Denver and told them to vote for Henry Wallace, one of the local guys got up and said, "We'll give you five minutes to get out of town." He got out and they switched to the AF of L as a separate union.

There were good management-laborer relationships during my era. They had a little trouble afterwards, but during my time there was a very happy situation. To give you an example, there were a number of Ivy League kids from the East, out working in the summer of 1950. One of them was a nephew of Arthur Bunker who was company president and he brought along his friends from Princeton and so forth out. As laborers they all had to join the union. After their first meeting they were amazed at how democratic the union was run. It was a revelation to them.

Swent: Was this your first time to join a union?

Aplan: Yes.

Swent: In Idaho you didn't?

Aplan: No, because I wasn't working as a miner. I was on the staff so I didn't have that problem.

Swent: At Climax?

Aplan: At Climax, when I went on staff I received $208 per month. I didn't get any pay raise going from laborer to staff, but it was a more prestigious job. And of course I moved around the mill and did that job as a mill accountant and in the chem lab. I still know a lot of the analysis from that whole damn plant--I've still got it in my head because I had to work with them. Every night by 4:15 the mill sheets had to be on the teletype to New York. When they came in to the New York office at nine o'clock in the morning, they wanted to know what the previous mill sheets looked like so that all had to be done one way or another. And so when I was in the chem lab and later in metallurgical accounting it was a pressure cooker if something happened--a sample was spilled or something like that in the chem lab, it was a mess because somehow you had to do something!

Swent: It was really run that closely from New York?

Aplan: Oh, yes. Not only because of an intense interest in the bottom line but they also wanted to closely correlate our activities with the smelting operation in Langloth, Pennsylvania, and with their sales organization.

Swent: One more question. Where were you living?

Aplan: In 1950 I lived in the company boarding house. In the spring of 1951, I and all the kids in Climax got the mumps. Since I was living in the boarding house they had to pull me out of there right away because all of the miners would worry about their family jewels. They put me in the company hospital. After a week or so I no longer was contagious, but my face was still swollen and they said, "Just take a pass and get out of here for a few days."

So I got in my car and drove down to Telluride. Just outside of Telluride at Pandora was a mine called Telluride Mines. It was later taken over by Idarado, a division of Newmont. The mill is still sitting there at Pandora. I went there last summer but it's not run as a mill anymore. Telluride Mines had a lead-zinc-silver operation, and the metallurgist was El Geist, Elton Geist, who was a year ahead of me at South Dakota School of Mines. He gave me a good tour of the mill. That was an interesting time period because the Rio Grande Southern--a very popular narrow-gauge railroad for us railroad buffs--was still running. And I'll pick up on that a little later.

Back at Climax, my most interesting work was on cassirterite flotation and on hyrdocyclone test work done in the summer of 1950. The hydrocyclone had been developed in Europe at the Dutch State Mines. At the end of World War II the U.S. commerce department sent experts in all the fields to evaluate the state of technology in Europe. One of the people sent to evaluate coal mining was Dr. H.F. Yancey from the Bureau of Mines--I'll talk about him later--and he was at the Northwest Experiment Station in Seattle on the university campus. Yancey was impressed by the hydrocyclone

which had been developed for coal preparation by Dreissen at the Dutch State Mines and Yancey brought the concept back to the States. It was used for several years in the coal industry and there were big ads that would say, oh, it's wonderful, it has no wear, etc., because that was for coal, but for ore it wasn't so good. Yancey's work and publicity about the device, as well as later sales options to Dorr-Oliver and Heyl and Patterson, encouraged its adaptation at U.S. coal preparation plants. Unfortunately, the excellent results with coal didn't translate well to abrasive ores.

The Climax mill metallurgist, Ed Frohling, had done his bachelor's thesis on hydrocycloning under Gaudin at MIT in 1947-48. He suggested cycloning the high-weir classifier overflow to obtain additional sand feed to the spirals and have additional heavy trace metal recovery. We made a 15-inch cyclone of heavy sheet metal, but after a short running time, the abrasive Climax ore slurry broke through the sheet metal and here we're dealing with a thousand gallons of slurry a minute going across the building and splattering against the wall. What a mess! [laughs]

So at that time Linatex had just come out. Linatex was a soft, unvulcanized rubber and it had tremendous resilience. They were using it a lot to line ore chutes feeding the grinding mills, because of abrasion. So we put a Linatex liner in the hydrocyclone. I was a still a laborer at this time, so I was given the job of doing that. I took Linatex and some rubber cement and lined the inside of this cyclone. Well, it was kind of like Bre'er Rabbit and the Tarbaby because I had glue all over me and everything I touched would stick to something. One way or another I got that thing lined with Linatex. It ran for months before our shop did a proper job of adding the Linatex lining. So that was one of the early-day cyclone uses with ores.

I think the first commercial use of a hydrocyclone in the U.S. in metalliferous ore beneficiation was by Al Kingman (South Dakota School of Mines & Technology class of 1935) at Tahawas, New York, at National Lead's titanium division--this is upstate New York, way upstate up by Lake Champlain. And that was probably the first use. About the time of our installation there was one at Telluride Mines, too, because Geist had been at Tahawas. So when he came out to Telluride he knew about it.

Swent: I interviewed Bob Clarkson; he worked with hydrocyclones very early and later manufactured them. [John Robert Clarkson, *Building the Clarkson Company, Making Reagent Feeders and Valves for the Mineral Industry, 1935 to 1998,* Western Mining in the Twentieth Century series, Regional Oral History Office, University of California, Berkeley, 1999]

Aplan: Oh, yes. Probably in the late forties or early fifties.

Swent: Did they have one at Bunker Hill?

Aplan: I never saw one at Bunker, but they may have had one. Who knows, but there were quite a few people messing around with cyclones '49, '50, '51. Because the abrasion was so bad with ores, until Linatex came along, they couldn't do it. Whereas with coal, which wasn't

abrasive, they didn't have many problems and I saw big ads in *Mining Engineering* about how good they were. They weren't really good for ores but we solved that problem. [laughs]

Water-Plant Foreman: Good Experience for Later Teaching

Aplan: Then one day the mill superintendent, Max Dessau, called me in and said, "The water-plant foreman has just quit. You're the water-plant foreman."

I said, "I don't know anything about water plants."

He said, "There are two books up there." [laughs] He said, "The foreman's gone."

For potable water Climax had several little retention dams on the side of Mt. Bartlett, plus a larger water retention ponds just below town called Buffehrs, further, they captured water running out of the Phillipson and White levels of the mine. These mine levels were located where the big pit is today.

Swent: Is that the Henderson Mine?

Aplan: No, Henderson is at Dillon. I'm talking about the Climax Mine at Fremont Pass in Lake county, whose county seat is Leadville. Only the lower or Storke level of the mine exists today.

The problem with the mine water was it contained about 15-20 parts per million of fluorine. Unfortunately, 15 or 20 ppm of fluorine will mottle the enamel on your teeth and lead to decay, whereas one ppm is good to keep the teeth (which are fluorapatite) in the fluoride form. So a lot of the kids raised at Climax in the thirties had false teeth; they lost their teeth.

In the camp we needed about 200,000 gallons a day of potable water for the houses, mill, mine, et cetera; not for the processing, but for drinking water systems and so forth. Before the new run-off came, they were short of water, so they had to divert tailings water. So the tailings came out of the plant, went down to a tailings pond, and they pumped the water back into the mill and re-used it again. They diverted some of it to a little dam just off the main property called Buffers, which would be bled into the potable water in order to make up any shortage. Remember I said we used a little pine oil in the flotation? Well, pine oil is very persistent. And before spring run-off came, the use of some tailing water made a very aromatic cup of tea. [laughter]

Swent: I can imagine.

Aplan: And there was an interesting story told. Now, before Max Dessau came in as mill

superintendent, the mill superintendent had been E.J. Duggan, who was quite a well-known mineral processing engineer. He had previously run the last Kennecott, Alaska, plant for Kennecott. This involved ammonia leaching of the malachite and azurite and some chalcocite--it was a fascinating plant.

Duggan was a very forceful individual and the water plant was under the direction of the mill superintendent. And people were coming to him and complaining about the pine oil in the water. He said "Oh, there's no problem." It wasn't until later that we found out that he had arranged for the janitor in the "dry"--the change room—to bring bottles of water up from Leadville for his use. [laughter] Since I was the water-plant foreman they would come to me and yell about their water, but I couldn't do a thing about it.

Swent: Would that pine oil hurt anybody?

Aplan: Oh, EPA probably wouldn't like it today, but I would doubt there was a significant problem. I'm seventy-five and I'm not dead yet. I know of several people who spent most of their professional lives at Climax and are still alive; the Windolphs, for example. I drank the water, with that pine oil. [laughs] But it did make a good aromatic of a tea.

Swent: It wouldn't taste good at all.

Aplan: A few years later they did away with that water source.

Anyway, in the water plant they took the mine water, used alum to flocculate fine particles, ran the thing over a rapid sand filter, a big vat full of sand and the alum would coagulate the fine particles as a slimy material which would stick to the sand particles and you would get clean water out the bottom. This is standard for a filtration plant. But we had to defluorinate, from 15 to 20 ppm down to about 1 ppm of fluorine and it was done this way--

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Aplan: From the rapid sand filters the water ran to vats of calcium phosphate. The fluoride would precipitate as calcium fluorides, CaF_2 , and the phosphorous would go into the solution--not much because we're only dealing with 15 ppm. And that would take the water down to about 1 ppm of fluorine. Since we had several tanks, we would take one tank off-line and use sodium hydroxide to remove the fluorine from the calcium phosphates as sodium phosphate. Then the vat was back-flushed with water and neutralized with carbonic acid. We would use either dry ice or a liquid CO_2 to make carbonic acid, H_2CO_3 , and neutralize the material. Then we would chlorinate the water and put it into the system. I learned a lot from the two books.

And so when I came here to Penn State I made use of a lot of this because we have a geo-environmental engineering degree, so when I have students studying Elements of Mineral Processing I'll tell them about use of a plant like this. It was probably the only plant of its kind in the country or in the world. Most of the plants that have fluorine--such

as Iowa, the Dakotas and so forth--only about 1 ppm and it's good--the teeth are made of mineral apatite, and you've got to keep it in the fluoride form. That's why you use stannous fluoride in toothpaste, to keep that surface in the fluoride form because the hydroxy form of apatite is soft. And so a little bit of fluorine is good, and of course a lot is bad.

Leadville at that time was a laissez-faire mining camp except there was no open gambling. The people from the attorney general's office in Denver used to love to come up and raid Leadville. It was close enough they could get up there in a few hours and they could have a nice raid. Usually they would raid the bars. The gambling was gone, but they had to have a raid of the bars to show they were busy.

And of course Leadville had a fascinating history. The thing about it though, was that the town--this was when I first went up there--1950--looked like it was made out of shacks, most buildings not painted, etc. About the only really classy-looking houses were the Healey House, which is now a museum, and the Public Service of Colorado and Bell Telephone Company houses. Well, I found out that if you painted your house they would come around and adjust your taxes upward. So people did a tremendous job of fixing up the houses on the inside but outside they let all the old unpainted boards stay there because if they painted it or they saw anyone making an addition they would come around and re-tax them. Sometime later the tax situation must have been changed because when I next visited Leadville about 1973, they had embarked on a major cleanup, fix up, paint up campaign. I was thrilled at how well the city now presents itself but still maintains its historical roots.

This laissez-faire attitude has a lot of valuable features to it as well. I've always enjoyed Leadville. Over the years I've stopped back many, many times. I've got probably a dozen books on Leadville and a couple dozen pamphlets and magazines and stuff like that. And I've got several hundred Western ghost mine books. I've got a lot of them. I'm proud to be a member of the National Mining Hall of Fame in Leadville. They have done a tremendous job of renovating the old high school building and installing a first-rate museum.

One of the interesting things Leadville has is the July Fourth burro races. They have a standard pack--you know, with a pick and a gold pan, etc., up to a certain weight, put it on the burro, and take it over Mosquito Pass. They used to run over to Fairplay in South Park. Fairplay was a very small town, but in the last couple of years there has been a tremendous building boom in Fairplay so Fairplay is ten times the size it was. I doubt if there were 100 people in Fairplay in this earlier era. Downtown in Fairplay they had a monument to Prunes, a burro. Prunes died in 1930 and was reputed to be sixty-three years old when it died, so there now is this monument to the burro. But anyway the burro race went to Fairplay and back. Now, today the burro race just goes to the top of Mosquito Pass and back.

I did some mountain climbing in Colorado. I shouldn't call it mountain climbing, I just walked up a big hill; I didn't know anything about mountain climbing; I walked up a

hill. I went up Mt. Elbert, the highest peak in Colorado, just down from Leadville, and at the top I ran into snow, sleet, hail, rain, fog--the whole works--so I had no view from the top. [laughs]

Swent: What time of year was this?

Aplan: This was July Fourth. Just adjacent to Climax is Mt. Arkansas. And I went up there twice, almost got killed both times.

Swent: Oh, my!

Aplan: Well, that's because I'm dumb. The first time two of us went walking up a big hill--and you know on many of these hills you get up here and it looks like--a crest is here, see, so you go up here and the crest is further up and you go up there and the crest is up there further. Well, we said, "It's about four o'clock and it's going to get dark before long," so we started back. And we came to a place--it was kind of a V-shaped crevasse in which snow was packed in--kind of a poor man's glacier up there. And we had to go down this thing. Now how do you go down it because at the bottom of the snow was a talus slope and if you broke loose going down you would really wreck yourself up on the stones at the bottom of the slope? So we finally figured out that--

Swent: You hadn't had to cross it to get up?

Aplan: We climbed up adjacent to it. But trying to climb down was very difficult, and so finally we figured out how to do it. You had to turn around and face outward, so you're looking down at the talus slope and then dig your heels of your boots in the snow as you went down.

Swent: So ski down on your boots?

Aplan: A lot more slowly. The next time I went up there was in 1953 when I was up there the second time. And Mt. Arkansas, as many mountains are, have glacial cirques where the glaciers--well, as you get near the top, there are two glacial cirques forming a kind of ridge. Well, it was rotted, you know, the rocks were pretty weathered and so forth, so you had to kind of straddle the thing and move along that way. When we get up there, of course we found a U.S.G.S. monument that was put up there in 1872 or something. [laughter] But as we were coming back, an electrical storm moved up the valley from near Leadville and you could see it coming. Many afternoons we would get a lightning storm moving up from Leadville up the valley--Arkansas Valley. This was at one side of Climax, right on the Continental Divide. One side the Arkansas goes down into the Arkansas River and ends up in the Gulf; the other side goes to the Pacific. And as soon as we got off that crumbly ridge, we ran. And it was on a very steep slope, but we ran anyway and got off; we didn't want to be the highest thing up there.

Swent: No!

Aplan: Anyway, I was dumb and I didn't know anything better.

I used to tour the state a lot with a friend of mine, Stan Shack, who worked for the Arkansas Valley smelter of Asarco at a place called Stringtown which was just south of Leadville--part of Leadville.

And then there were the Scussel twins, Hank and Gene, who had gone to Texas Western. Well, at that time it was Texas College of Mines and it was changed to Texas Western and now it's the University of Texas, El Paso. Anyway, they had graduated in mining there and they were working at Climax.

And later when I was up there the second time, Cal Brennan, whose father was chief metallurgist for the Electro-Met Division of Union Carbide, he and I used to tour the state. It turned out later, when I worked for Carbide, Cal was working for International Minerals and Chemicals across the street. [laughter] He had gone back to Carnegie Mellon and finished up his Chem-E [chemical engineering] degree.

The electrical storms could be rather nasty. If they hit the central station then suddenly the mill would be deathly silent--nothing was running. And of course there was pulp running every place. Well, they had designed for that so they had directed overflows and good drains and they would get the mill back on line pretty fast after the power came back on.

There was another interesting thing which I have done a lot of research work on since I've been here, and I incorporate it into my teaching; this is suspension stability. I don't know of anyone in mineral processing that spends this much time on suspension stability, but every place I've been, suspension stability is important. At Homestake it was important: if you tried to shut down the CCD pilot plant, once you got the solids in the agitators down to about 10 or 12 percent the load would drop like a rock and then you would run the risk of sanding the agitator. To cure this the agitators had high-pressure air-diffusers we could use to keep the suspension stirred up, but I had also run into suspension stability problems at Union Carbide and at Kennnecott.

But the biggest one was Climax. Our tailings went down the mountain. And if you've ever driven by there, you've seen the big tailings ponds that sit on top of the old town of Kokomo. In my era, though, they didn't go as far as Kokomo, because Kokomo still existed. The tailings water was decanted and pumped back into the mill. Because we had a coarse grind, the material settled very rapidly. And in order to keep it from settling rapidly you had to have at least 50 percent solids. Now, when you shut down and start up a mill, you've got water all over the place and you don't have anything remotely resembling 50 percent solids, so you run the risk of plugging that tail line.

What they used initially was a critical slope beside the mill. They had a very, very flat slope, with essentially no elevation on the pipe at all. And if it was going to sand anyplace, that's where it would sand and we could drain to a dump pond. When I first went up there they had a redwood-stave pipe, dating from--I don't know--1915 or

something. And they had a snowshoe patrol with snowshoes and axes, so if anything happened to that pipeline they went out and chopped a hole in the pipeline to keep it running because if it ever sanded up and froze, they would be shut down until spring.

Now later the thing was cured in a different way. They put in a thickener and had instrumentation on the thickener so that nothing less than 50 percent solids could get into the pipeline. The other thing they did and this was I think developed by Warren Wilson who was at Colorado School of Mines and later was president of the School of Mines at Rapid City for three or four years: they had a system we could call jumps and risers. The tailings were coming down a line and ran the risk of having the coarse particles settle out preferentially to the fines, and then all of a sudden the line would plug. So what they did was to install a kind of silo, and the tailings dropped down the silo would remix the slurry. Several drops like this in the tailings line would keep it from sanding. I've been able to incorporate a lot of these practical things from industry into my teaching and research.

During this time the Denver and Rio Grande Western was still running several narrow-gauge railroads. They had shut down the line from Gunnison to Montrose, but they still had a line that went over Marshall Pass into Gunnison. They still ran the line that came from Salida, followed the Marshall Pass line, and then split off and went into San Luis Valley so it ended up in Alamosa. Then it went to Chama, New Mexico, and then the line ran roughly along the border between those two states and ended up in Durango.

They had one line then went down to Farmington, New Mexico, and this was--you remember that in the fifties there was a big oil boom down there, and so they brought pipe down, train after train of pipe. Then they also had another branch that ran up to Silverton. Now there is sixty-three miles of the line from Antonito, Colorado, to Chama, New Mexico, that is being operated called the Cumbres and Toltec. And it's still running; it runs over Cumbres Pass and runs as a tourist operation. It's owned by the states of New Mexico and Colorado. They bought the roadbed together with some of the original rolling stock, including the rotary snow plows and so forth. And they have a big tourist operation. There's another big tourist operation, the Durango and Silverton, that runs every summer.

Then there was another narrow gauge called the Rio Grande Southern. It started at Ridgeway, which is just north of Ouray. The problem is they couldn't connect Silverton to Ouray. They got over Red Mountain Pass--but not easily. They had to have switchbacks and a turnstile and they had a lot of problems. You know, they had to put the locomotive on a turnstile and then take it off. And then take a car--anyway, it was a mess. But they couldn't get all the way down the million-dollar highway area into Ouray, so the Rio Grande Southern came into existence--this would be 1885--and starting in Ridgeway, runs over to Telluride, then it went over Lizard's Head Pass, into Rico, Delores, and then around the south of the San Juans and back into Durango.

Rico was where they got a lot of the pyrite to make sulfuric acid for the uranium boom. So Rico was running until the uranium boom started going down--well, actually

until the copper smelter gas--the sulfuric acid started displacing it. In addition to a locomotive train, they put in what they called the Galloping Goose. They took an old Reo Speed Wagon, pulled out the differential and put in a sprocket and a chain drive, they pulled off the wheels and put on railroad tires, and then they added a box on the back. There were seven geese originally. And the reason they were called galloping geese is because the Rio Grande Southern used a very, very light rail--some of it was as light as 20-pound rail. And if you looked at the Rio Grande rail, you would see it wiggle and snake along--and in both the horizontal and vertical directions, so as you rode along in the thing it would bounce, i.e, gallop. And where the goose came from I don't know. But anyway, Galloping Goose. And they had seven of these geese. One of them is gone, number one, but the rest still exist. Three of them are at the Colorado Railroad Museum in Golden, one of them is in Knott's Berry Farm, one is in Delores, and one is downtown Telluride. And I've seen them all. I went to Knott's Berry Farm and the one thing I wanted to see was the goose. [laughter] But even though they had all these narrow-gauge lines and I was just north of Salida, where there was the main transfer station from narrow to standard gauge, I never rode a narrow-gauge then. I'm now a narrow-gauge buff, so I've ridden all the narrow-gauge lines that exist, including the East Broad Top which still exists in Pennsylvania. But in those days I didn't, which is a shame.

Let's talk about the second time I was up at Climax. 1953.

Return to Climax in 1953 to Work on Tin Recovery

Aplan: I was at the University of Washington from September of '51 until June of '53. And then in September '53 I was going to go to MIT, so that summer I went back up on the Moly Hill. They had started to move the camp from the hill down to Leadville and so I looked for a room in Leadville.

Swent: Why were they doing that? Because they were going to mine it?

Aplan: They were going to mine in a lot of that area and plus I think they didn't want to be in the housing business. There is always maintenance and all that stuff. They essentially sold the houses for next to nothing and helped truck them down to Leadville and reset them.

So I looked for a room in Leadville and I first stayed in the Vendome Hotel for a couple of days. And I had forgotten all about this until I read Frank McQuiston's oral history. [Frank Woods McQuiston, Jr., *Metallurgist for Newmont Mining Corporation and U.S. Atomic Energy Commission, 1934-1982*, Western Mining in the Twentieth Century series, Regional Oral History Office, University of California, Berkeley, 1989] And he describes living in the Vendome Hotel. He was working for Newmont at the Resurrection Mining Company at that time, during World War II. And he describes the Vendome Hotel. This was probably built in something like 1884, and it was originally called the Tabor Grand and then later it was changed to the Vendome. Well, today the

Vendome sits kind of forlorn, shorn of its magnificence, across from the Golden Burro Cafe.

But when I stayed there, I stayed on the second floor. The hill slopes down rather precipitously and I had a back room and as you looked out the back room you weren't just one story high--in the first place they had these very high stories, particularly for the lobby and then the hill slanted down sharply. The fire escape was a box and in the box were two chains and about every foot was a cross bar. And you threw that thing out the window and then climbed down. Well, of course, as you imagine, when you had a long ways to go it's going to swing back and forth. [laughs] I had pretty well decided if there was a fire and I had to get out I wasn't going to go out that way. [laughter] But a lot of hotels had fire escapes like that at that time--just a box --you opened the box and you threw the chain out. I finally went over and got a room at the Quincy Hotel, which is still sitting on Harrison Avenue.

In the two years that I was gone they had built mill number three and were building mill number four across the street from the original mill. And I was working on tin recovery using a thing called a tilting frame, and on mill recovery problems.

I go through Leadville every few years--the last time was last July--July, '97--and it has had a strong shape-up over the years. They've painted the houses, the old original Tabor House is well-painted and fixed up and available for tourists, the National Mining Museum is there in the old high school up on the hill, which is a wonderful operation; they have really done just a magnificent job on that. And so the whole town now looks a lot different from what it looked like before, because I guess they're not taxed for putting paint on the outside of the buildings. [laughs]

They're running quite a good tourist business. There's a good book store on the main street--of Western books. I always stop there and buy a few books. I probably leave close to a hundred bucks of my money back there each time. And then skiing: there is Cooper Hill just a few miles away where the Tenth Mountain Division trained in World War II, but you know they are close to Breckenridge, Keystone, A-Basin, Copper Mountain, Vail, and all those places are very pricey, but you can stay in Leadville a lot cheaper and drive over.

Colorado Highway Department, in my opinion, is probably the best winter highway department in the country. I had been over Loveland Pass--this is before the Eisenhower Tunnel was built, so this would be in 1951, something like that--I had been over Loveland Pass in a blizzard at three o'clock in the morning and met five pieces of snow removal equipment including two rotary plows. So what Colorado does is they take some passes such as Independence Pass between Leadville and Aspen and just let them snow in. They don't bother with them, just block them off, and you can go--you'll be welcome to go over them the second week of June! But those that they do keep open, they do just a tremendous job. I've been over a lot of passes and the highway department has really done a magnificent job. And so I tell you, I vote those people number one.

In addition, there were slag heaps on both ends of Leadville and there was a big slag heap just south of Leadville at Stringtown. the old Asarco Arkansas Valley Smelter. It was a lead smelter. They are removing the slag at the east end of Harrison Avenue, the main drag. For quite a few years, the Asarco site has been a Superfund site, and they've got that pretty well camouflaged. I was impressed at what they've done there.

I guess I could summarize. It was a wonderful learning experience. I still keep friendships after fifty years, particularly Lou Cope, who was on the staff with me at the--he also came out of Texas College of Mines. Lou is a consulting metallurgist in Denver but Lou and I were on staff together, so I always keep up with Lou. With Ed Frohling, who is now down in Tucson, and with Dixie Crismer who later married Bud Windolph, so I've got one Christmas card to go to two good friends--that goes to Bud and Dixie at the same time. So I had a wonderful learning experience and I am really thankful. I've written up the byproducts plant in one of the rare-earth volumes published by TMS [The Metallurgical Society], edited by R.G. Bautista. That's it. Let's quit.

Swent: That's a good place to stop.

[Interview 2: July 21, 1998] ##

Swent: I did have a few questions from yesterday. You referred several times to cars and I wanted to know what kind of cars you were driving?

Aplan: [laughs] Well, I inherited from the family a 1937 Oldsmobile. It was in pretty good shape.

Swent: This was when you were in college, an undergraduate?

Aplan: Yes, when I first went back to college I intentionally didn't have a car and before the war there was no money for any cars or that kind of foolishness, but after the war I had money to buy a car. Well, you couldn't buy a car as a matter of fact, but I had money. I purposely did not want an automobile because I knew I had to study and going back to school after being out for several years is tough. And I sweat blood being reeducated because, you know, chem, math, physics--I was back into the old books and I didn't understand any of it, or what I had, I'd forgotten!

When I went to Homestake in '47 I got the 1937 Oldsmobile. And I drove that until I was at Climax a while. And then I started having trouble with it so I bought a 1950 Plymouth which turned out to be a very good car. I got something like 106,000 miles and the head was never off that car.

Swent: Did you buy it new?

Aplan: Yes.

Swent: How much did you pay for it?

Aplan: Way more money than I had. Gosh, I'm trying to think, maybe $2,000 or something like that. I can't remember.

Swent: And did you make payments on it?

Aplan: Yes, I took out a loan. But I had a very short loan; I had to pay it off. And I kept that car until half-way through my experience at Union Carbide.

Then I made the mistake of buying a Rambler and that was a real turkey and then I got a Plymouth station wagon. And since I've been at State College I've had a series of Oldsmobiles. Often for our second car we've used a VW Rabbit and Mazda—currently we've got a Mazda. But I keep a car until it dies. Anyway, that's how I handled the cars.

Swent: Did you do some of your own mechanical work on it?

Aplan: Very little. I'm not much of a mechanic on automobiles and I quickly learned that if you're ignorant to leave well enough alone. [laughter] Plus I had another little problem. I have a slight defect in my inner year so if you get under and try and do things under the dashboard, I become dizzy.

Swent: You lose your balance, yes.

Aplan: So a couple of times of that--and you feel lousy for a couple of hours after that.

Swent: Well, that was one question I had.

Aplan: Over the years I've had very good luck with Oldsmobiles. In the family we've had an Oldsmobile since 1930.

Swent: And that's one of the few brands that's still around from those times, too. [laughter]

Another question I wanted to ask was about movies. You mentioned going to music but you haven't said anything about going to movies. Was this a part of your formative experience as a child growing up?

Aplan: Well, when I was a kid movies were fairly expensive. The movie theater was in the next town, and the theater in Pierre used to burn tires, old tires, so kids would roll a tire three miles over to Pierre as the price for admission to get into the theater. [laughter]

Swent: Why did they burn tires?

Aplan: I don't know--cheap fuel. They had a big furnace and they threw the tires in. The theater

owner was quite an old character anyway, but anyway that was the way that was done.

Swent: So if you came with a tire you could get into the movie?

Aplan: Yes. And as you know the money was short in the forties or thirties. For a couple of years in Ft. Pierre there was a small theater which had sixteen mm [millimeter] movies, but they were a grade B triple minus! And boy--[laughs]--a lot of kind of shoot'em up--the black hat and white hat types. When I was in college, I didn't go much to movies; the schools I went to were very demanding. During the week you never would go to a movie, period. On weekends is when I would go see a movie. When I went back to MIT I was running scared. You know, I can't fail on this one, and that was nose to the grindstone.

TV had just come in and in the grad house at MIT--this would be '53 to '55--in the Graduate House they had one room that had a TV set up. And on Wednesday I would go down and hear Groucho and Dragnet. They were half-hour programs back to back. And on Saturday night I would hear Jackie Gleason for one hour. And that was the extent of the TV. And the rest of the time study and work and I was in the lab.

Swent: What about radio as a child? Was this something in your life?

Aplan: Well, you always had a radio but, again, in central South Dakota there were only a few stations. There was one fairly large station--WNAX--out of Yankton, which is still going. This was a station that gave Lawrence Welk his start.

Swent: Right, I was going to ask you about Lawrence Welk, too.

Aplan: And it was kind of an interesting station--quite well done for a small community. Yankton was quite small. And it did quite a good job, but you began hearing, for instance, the WNAX brass band, the WNAX Bohemian band, the WNAX studio band were all oom-pah, oom-pah, oom-pah. [laughs] It was all just the same band. And I would hear a few radio programs--you know, but often, even during high school, I spent a lot of time studying. And I guess Saturday and Sunday--you know, Sunday nights--we had Jack Benny. And so I guess Benny and Fred Allen and occasionally you would hear Colonel Schwartzkopf and Gangbusters. [laughs] And as a kid it was Little Orphan Annie, the air adventures of Jimmy Allen, and a few like this.

Oh, and the other thing I did as a kid was about six o'clock at night Amos 'n Andy would be on for fifteen minutes. And then about '31, in there, when Byrd was down to Little America they used to flash a signal--I think it went from Little America to Buenos Aires up into Newfoundland someplace and then back to New York--and you would get this thing and on AM they would rebroadcast the shortwave. [who-wa-wna--speaking nasally] You just couldn't hear anything for the static.

Swent: But you knew it was coming.

Aplan: But you knew it was coming and you would get enough and it was quite interesting.

People were very fascinated by Byrd's expedition. And he had taken a Boy Scout with him, Paul Siple, who later became quite a well-known earth scientist.

But basically I guess I didn't listen too much. And then we had a local station, but the local station did mainly hospital reports and played records. And it was about the only form of communication--during the thirties, the rural telephone system went out entirely, they couldn't afford to maintain the lines, so that was all gone. And I was in a big county and well spread out. In the northern Stanley County there were probably five or ten miles between some neighbors. There weren't good roads, so a lot of the ranch families you would see in November when they would really stock up on food and you wouldn't see them again until late March, maybe April. And so the radio did all this stuff on the hospital and then anyone wishing to communicate, the radio was the means. There was no rural electrification--rural electrification was a wind-charger, with usually a 12-volt battery that ran a radio; that was rural electrification. And so the radio was their means of communication with outside. They couldn't get back, but anyone in the hospital, anyone wanting to deliver a note, that was broadcast over the radio station. It had no formal programming, it was just--

Swent: This was not ham radio, this was regular?

Aplan: No, no this was the regular station. The station still exists but it has more generous days these days than it did back then. And one woman ran the thing. And did the whole thing!

Swent: A key person in the community, wasn't she?

Aplan: Well, she was the means of communication to the whole rural area, which was very large.

I kind of regret I didn't do more listening to the radio, because I have since developed a tremendous interest in big bands and jazz. I never listened to hardly any of the big bands as a child and yet now I've got a big collection of air checks from the big band era, but I never heard any of these back then.

Swent: What did you do for--did you have dates? Did you have dancing?

Aplan: Well, in a small town you're kind of restricted. There were quite a few dance halls during the thirties. I think there were three of them in town but they were for an older group. Kids wouldn't go there. So mostly, you know, we hunted jack rabbits and hiked and played cowboys and Indians up on the hill. And Missouri River was close, we did a lot of hiking down the river. And then we had some old hand-made rowboats and were out on the river.

Swent: What about Indians? Did you know Indians, real Indians?

Aplan: Well, yes. There were Indian reservations on about two and a half sides of Fort Pierre. To the north is the Cheyenne, to the south is the Lower Brule, and to the southeast is Crow Creek reservation.

Swent: And were these children in school with you?

Aplan: Yes, but it worked out this way: the bulk of the Indians went to Indian schools. There was one in Pierre and there was one up north and there were a number of them scattered around. Quite frankly, the government education stunk. That was a lousy education they gave the poor Indians. You know, after ripping them off the land they gave them a lousy education, so some of the Indian families would move in to town.

Also you must realize that in central South Dakota the mountain men had been there. The Verendrye Brothers were through there in 1743, and then the Lewis and Clark expedition went through there in 1803. Because of the mountain men, a good many of the Indians carried French names: Roubideau, LeBeau, Frenier, et cetera, etc., etc., so that there were a lot of people that were part Indian. In my class, say out of about fifteen, there was one girl that was Indian, part Indian, but I don't know what part, 25 or 50 percent, something like that. And two of the boys in the class married part-Indian girls.

There had been a long string of important people who were Indian or part-Indian. Scotty Phillips, who was very important in early day Dakota, had an Indian wife. Scotty Phillips is the person that saved the buffalo. The northern buffalo herd was extinct about 1885, and the southern buffalo herd in the Kansas, Oklahoma area was extinct by '80 or '81. So there was an old Frenchman by the name of Dupree--you may remember the town, there's a town, Dupree, South Dakota.

Swent: Yes.

Aplan: Well, Louis Dupree had saved about a dozen buffalo. And Scotty Phillips bought those buffalo from him and built a buffalo pasture about 1890 in Fort Pierre. That herd was eventually dissipated in the early thirties, but all the buffalo in Wind Cave National Park, all of those in Custer State Park, all of those in Colorado, etc., are descended from that herd. The only other source of buffalo were some buffalo that came from Canada into Montana. And that was kind of a tragic thing because in their infinite wisdom the Canadians had rounded up the buffalo but they mixed in the wood buffalo with the plains buffalo so they have bred those two distinct species out of existence. But in South Dakota they all descended from the Phillips herd. The Phillips family was very important. They were all part Indian.

Related to the Phillipses was a man by the name of Waldron. He went to Annapolis. In the beginning of World War II, he was a lieutenant commander and he was commander of Torpedo Squadron Eight. And Torpedo Squadron Eight was the first one in at the Battle of Midway. Out of thirty men, one guy survived. Because the U.S. was attacking the Japanese at extreme range and there was cloud cover, they got lost, so when it came time to hit the Japanese, the fighters, the bombers, and the torpedo planes were all separated. The torpedo squadron went in on the deck first and released torpedoes. They didn't accomplish anything, they didn't hit anything, but what they did do is pull the high Japanese air cover down. They saw these Americans and came down and got them. Just

then the U.S. dive bombers broke out of the clouds and they ended up sinking four Japanese aircraft carriers--three that day and one the next day. But only one man, Ensign Gay from Texas, got out. But anyway, the commander of Topedo Squadron Eight was Waldron of Ft. Pierre, South Dakota.

Swent: So he did not survive.

Aplan: He didn't survive.

There was another Phillips who also was an Annapolis graduate who commanded a new destroyer. The kamikazes got him so he didn't survive either. And there was another one who was a major in the marine corps. So that Phillips family was something else. The family members ended up as U.S. attorneys, et cetera. That was a classy family.

And then the sheriff of Stanley County for many years was Bill Powell who was Indian. Kind of interesting, in those days an Indian couldn't go into a bar and drink. That didn't come until Eisenhower's time. And so here the sheriff couldn't legally go into the bar. [laughs] But he was a well-known man, he was a buffalo hunter, he had done everything--Bill Powell could do anything, yes.

And then later the district attorney--Raymond Roubidoux was State's Attorney of Stanley County, so there was a lot of liaison with Indians. And as a matter of fact in central South Dakota the Indians are going to be bred out of existence. Give it another hundred years.

There were several other kids in my high school that were part Indian--quite a number of families. And as I said, some Indian families would purposely move into town so the kids could go to the school and stay away from that Indian school which wasn't much good. But even at the Indian school I used to see, over by the Indian school in Pierre, there were Indian families that would come--this was in the thirties--come live in tents. And you know how the Dakota winters were.

Swent: Yes.

Aplan: Okay, and the kids went to the Indian school. Well, it was better than the alternative.

On a personal note, I've already pointed out that my grandmother's brother and sisters had married Indians.

Swent: That was before we taped. You hadn't mentioned your connections.

Aplan: Okay, my grandmother Aplan, whose name was Leaneagh--we originally thought it was French, and there's a lot of French in that family, but that name may be Irish. She was orphaned in the Dakota Territory in the early 1880s, had to be evacuated out of Wounded Knee area in 1890. She was orphaned and her grandmother brought the whole family out to the Dakota Territory at that time because her grandmother's brothers were with--well,

one of them was Red Cloud's interpreter. This was the Janis family, Antoine and Nicholas Janis. In fact, Antoine Janis is buried next to Red Cloud down on the Rosebud [Reservation]. Her brothers and sisters married Indians so that anyone with a name of Janis, Leaneagh (which has also been Americanized to Leonard), or Iott (it would be pronounced "e-o", I guess, in French), are some kind of relative of mine.

Then my brother's first wife was Indian, and so I have four nieces and a nephew that are part Indian; they're enrolled members at Cheyenne Agency. One of them is a policeman in Sturgis, one of them is a nurse working in Colorado, one is a bank accountant in Minneapolis, one is a teacher--so they've been very successful. One works for a radio station in advertising and graphic displays and stuff like that. So they've done quite well. Gone to college, you know, and they did well. But this is not atypical, particularly in central South Dakota, as I said. And you couldn't tell that they were Indian.

Swent: No. How was Roubidoux spelled in that area? I've seen so many spellings for it.

Aplan: He's now an attorney, or he was. Maybe he's dead now. He was an attorney in Rapid. I think it's R-I-B-I-D-E-A-U-X. And of course a lot of those things have been anglicized. With my own name I can hardly complain about that.

But there are all kinds of connections like this. In fact, there's one that kind of tickled me. One of my playmates was a red-headed guy and we used to go play cowboys and Indians and we never let him be an Indian because we said who ever heard of a red-headed Indian? Well, this guy went in the army and married a part-Indian woman in Oklahoma, and his daughter was red-headed. And when I got out of the army I saw another classmate and he said, "If you see Lyle, you better keep your mouth shut about that red-headed Indian." [laughter]

Swent: All right. Now, one other little question. I kept asking you what kind of clothes you wore and you just said work clothes, but I'd like to be a little more specific. When you, say, think back to Leadville, for instance, when you were working there at Climax, were you wearing--what were your pants made of? Were they denim, or khaki, or wool, or corduroy?

Aplan: Well, usually I would wear a khaki shirt, something like that. The pants would be often khaki or slate gray, something like that.

Swent: I think this was before Levi's and denims had become standard.

Aplan: Well, the other one that became popular later, too, was when I got back to MIT, the Harvard uniform was khaki pants and a charcoal gray jacket. That was the uniform.

Swent: That was different, but the denims had not come in as work clothes, yet, except for farmers.

Aplan: Well, it was very common for farmers and ranchers. My grandfather sold all kinds of "Levi's." And there were two major manufacturers, Levi's and H.D. Lee, who made most of those jeans.

Swent: But other workmen hadn't taken that on quite yet?

Aplan: Well, a lot of them used bib overalls, a denim bib overall.

Swent: What kind of shoes did you wear?

Aplan: Well, originally we just wore some kind of work shoes.

Swent: Were they boots or shoes?

Aplan: No, they were up above the ankle, but most of them were not steel-toed yet at that time. The steel toe became more popular probably in the mid-fifties, in there, and it was steel toe. And then by 1960, you couldn't get into an industrial operation without a steel-toed shoe.

Swent: Right, but in the thirties, in the forties it was still--

Aplan: Sometimes you had them, sometimes you didn't. I think I had steel-toed when I worked at Homestake.

Swent: What were the soles?

Aplan: Just kind of a composition. It looked not unlike conveyer belting--something about like that. There was a woven fabric cast into it and it had some kind of knobs on the sole to give you a little bit of traction.

Swent: What did you do about laundry?

Aplan: Laundry? Got to think.

Swent: There were no laundromats yet. And there were no drip-dry clothes. Did you send them to a washer woman?

Aplan: Obviously I did. I must have. When I was at the School of Mines I used to send the package home because you could mail a package quite cheaply, but when I was working, I mean, no way was my mother going to do the work clothes. [laughter] Obviously I talked to the landlady and said, "Who does work clothes?" In fact, in my mind I'm sure that was what was done. I'm sure it was--

Swent: A wash woman?

Aplan: Yes. And of course there were a lot of them because--I said the boarding house I stayed at

there were quite a few people working at Bald Mountain underground, so there were quite a few.

Swent: Yes, those things have all gone out. No wash women any more. [laughs]

Aplan: I know. Well, of course they--when I stay in Lead in the summertime up by Terry Peak, why, I come down a couple of times a week and do a big load.

Swent: But you do it yourself at the laundromat?

Aplan: Oh, yes.

Swent: If you anybody told you as a boy that you would be doing your own washing, you probably would have hooted, wouldn't you? [laughs]

Aplan: Not now! [laughter]

Swent: That's right. Times have changed a lot. Well, I guess we're ready to move on now. Had you pretty well finished Climax, do you think?

Aplan: Oh, yes, I've done that.

IV TEACHING AND GRADUATE STUDIES, 1951 TO 1957

Assistant Professor of Mineral Engineering, University of Washington, 1951-1953

Aplan: After fifteen, sixteen months at Climax I got restless and I thought, well, maybe I ought to consider moving on. And out of the blue I got an offer, or I got a letter from Don McGlashan who was my professor at Butte, saying that the University of Washington was looking for an assistant professor of mineral engineering, specializing in mineral processing. So I said, well, that sounds pretty good, I think I'll give it a whirl. I didn't realize it at the time but there weren't many people that had even a master's degree in that profession in the country, so I was accepted.

Swent: And what was the date on this?

Aplan: This would be September of 1951. And I stayed until 1953. The School of Mines at the University of Washington and it had been changed to the School of Mineral Engineering of the College of Engineering.

Swent: This was in Seattle?

Aplan: This was in Seattle.

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Aplan: --probably about a year or two before they had combined the School of Mines in with the College of Engineering, so it was a separate School of Mineral Engineering in the College of Engineering. And they had done that when Dean Milnor Roberts had retired. He was quite a famous mining man in the Northwest and in Alaska.

The director of the school at this time was Drury A. Pifer. And they had three departments of ceramic, metallurgical, and mining engineering. They had about three faculty in each and I was assigned to the mining division. It wasn't uncommon that the mineral processors would be associated with mining departments in the eastern part of the

United States, but not in the West. Seattle was an exception because there was a lot of coal mining in the State of Washington. I taught everything in processing: I taught mineral processing, flotation, hydrometallurgy, industrial minerals, ore microscopy, etc. I did all the labs, had to prepare all the labs myself.

Swent: Were you replacing somebody who had been there?

Aplan: I replaced H. Gordon Poole, who had gone to Case, Case-Western Reserve in Cleveland. And so I taught all those courses, plus we had a prospector's course, kind of an adult education prospector's course, which was kind of unique.

I had a fairly heavy teaching load. One term I totaled it up and I got in at eight o'clock in the morning and I left at five o'clock or after at night. And during that time I had two free periods in the whole day--hour-long periods--two of them during the whole day.

Swent: This was your first stint of teaching, then, wasn't it?

Aplan: Well, at Butte I had been a graduate assistant, so had to run all the labs in processing at Butte. And at both jobs it was kind of interesting because many of the students were about my age. At twenty-seven I was the youngest Assistant Professor in the College of Engineering, the University of Washington. In those days you didn't get promoted very rapidly, so often you would be forty-five before you became an associate professor, so a little different than today.

Pifer had an interesting history: he'd graduated from UW in the early thirties. He found a job in South Africa and he stayed in South Africa working in the diamond and the gold mines until after World War II. Kind of an interesting sidelight, a few years ago I saw a review of a book called *Innocence in Africa*. It was published by Harcourt Brace in 1994. And the author was Drury A. Pifer. I said, Huh? And so I got the book and I went to the back page. On the slip cover it had his picture and it was certainly Drury's son all right because he looked almost like his father. I had actually met the son a couple of times. He had started as a student in the liberal arts at UW during the period I was there and his father had introduced me to him on a couple of occasions. But it's a fascinating book on being an expatriate in South Africa in that period.

Swent: I have actually read that.

Aplan: You did?

Swent: Yes, it's very good.

Aplan: Well, for the record, the interesting part was that young Drury Pifer and his sister were born down there so he didn't remember much of this, but his mother was a prolific writer and wrote letters home to his grandmother. And he got ahold of all of those letters from the grandmother and was able to put this whole story together. I can recommend the book.

It's very well written. He has a tremendous command of the English language, but--I would like to get ahold of him and talk to him. He wasn't very cognizant of the mining industry or its history. You know, he acted like, well, his father had to go to South Africa for a job that wasn't too good down there--but those depression-era times weren't good for anyone! And he wasn't cognizant of the Depression in the States, either. While he didn't fully understand, it's still a very good book and a fascinating book. And interestingly enough, many of the people I was with at UW in the period wrote me and said, "Are you familiar with this book?" [laughs] They'd all picked it up, too. But the name Drury A. Pifer was so unique.

Swent: Yes.

Learning About Coal Preparation and Processing

Aplan: The school itself had a good faculty. Pifer was a mining engineer, taught mining. They had Joe Daniels who handled--he was an MIT graduate from, oh, I don't know, 1910 or something; he handled coal preparation--the only coal preparation course taught in the western part of the United States--so I was able to refurbish my coal credentials of years ago. He also taught iron and steel production.

Jack Finley was a Houghton graduate and he handled non-ferrous metallurgy. Mel Pechet (he didn't pronounce it in the French manner) did geology. He was from Harvard. Jim Muller, out of Ohio State and University of Missouri-Rolla, and MacDonald taught ceramic engineering.

I audited Daniels' coal prep course and Muller's crystal chemistry course. Both of them were excellent courses and they were very good teachers. Also in the same building was the U.S. Bureau of Mines Northwest Experiment Station which was one of their principal coal preparation research stations.

In those days the Bureau of Mines stations were on university campuses: on University of Minnesota campus, on the campus at Berkeley (the thermodynamic station was there at Berkeley in the Hearst Mining Building), at Oregon State and Albany et cetera, etc., etc., around the country.

And the coal station at the University of Washington was in our same building—Roberts Hall. The school had two large process bay areas and they had also added a mezzanine for some offices and labs, so I was a half floor above the Bureau offices and so I got to know Dr. H.F. Yancey and Max Geer very well. Those names are classic in coal preparation literature. I had long talks with them and they were a big help.

I learned a lot about coal. And one of the very fascinating things is that during World War II they had sent experts over to Europe to find the state of technology. And

the state of the technology in coal preparation was the bailiwick of Dr. Yancey and he saw the hydrocyclone that had been developed by Dreissen in Holland and he brought it back to the U.S. And it quickly became very important in coal and by the time I got to Climax it was starting to come into the ore industry. And today no Dorr rake classifiers, no Akins spiral classifiers--essentially 99 percent of classification is done by hydrocyclones. They're small and cheap--not quite as efficient as the others, but a lot cheaper and take up essentially no floor space. Yancey and Geer were doing research in coal jigging and heavy media processes, in suspension stability, on process analysis, online instrumentation, et cetera. And so just by talking to them I picked up all of this information. And of course, you know, I walked through their pilot operation almost every day so I knew pretty well what was going on.

There was an interesting cooperative fellowship program between the University and the Bureau of Mines. They were in the same building and under the co-op program the Bureau of Mines gave a student a fellowship and a little stipend and of course got a waiver of tuition. He did his academic work in the School, he did his research work in the bureau, and ended up with a master's degree, so it was a nice cooperative program.

Swent: How was it administered then? The bureau was in charge--

Aplan: --of research, and Geer and Yancey were adjunct faculty and certified to be thesis directors and so forth. When there was a thesis defense they showed up at the thesis defense as well as the regular faculty.

Swent: Was this special there at Washington or was this standard?

Aplan: No, a number of schools did that. And in my era there were two students like this: Farlow Davis, who had graduated from South Dakota School of Mines and has just retired from San Manuel, and U.K. Custred who was a University of Kentucky graduate and later did most of his professional work in the Florida phosphate fields.

But going way back, going back into the thirties was a man by the name of Julian Parton who had graduated here at Penn State. He later came back East, did some of the very early work in coal flotation, and ended up as CEO of Lehigh Navigation Coal Company, the largest anthracite producer. After me came Al Duerbrouck who got his bachelor's from Idaho, and Stan Jacobson who had a UW bachelor's degree. They were both in that cooperative program and they spent their professional life mostly with the Bureau of Mines and the U.S. Department of Energy. Duerbrouck was the highest-ranking coal preparation engineer in the government when he retired. Also, going back into the thirties, were some well-known people from UW. One was Oscar Tangel.

Swent: I've heard that name a lot.

Aplan: He ended up at Battelle. Another UW grad was Rush Spedden who went to Montana School of Mines under Gaudin and then followed Gaudin back to MIT and he was later on the faculty at MIT. Then he was Director of Research for Union Carbide Ore Company

and later Director of Research for the Kennecott lab in Salt Lake City. He was my boss for quite a number of years.

Still another UW grad was F.T. Davis, Casey Davis, who ended up as Director of the Colorado School of Mines Research Institute. My path would cross all of theirs later on professionally, as I keep saying on and on, what goes around, comes around.

I had another learning experience there because of a very famous chemist in the Chemistry Department by the name of Tartar. His specialty was in micelles and surface active agents, i.e. detergents. They were holding a large colloid symposium and I went over and got to see all the big shots in colloid chemistry at that time such as Peter Debye.

One other kind of interesting aspect. They had a lot of ore samples around from Kennecott, Alaska, some really neat ore samples. And they also had some old equipment. One time I was down in the basement rummaging around and said, "What is this?" And I looked down and it was a pilot-size McQuiston tube. [laughs] The McQuiston tube was Frank McQuiston's father's invention; it was a cylinder, a long cylinder, usually on nearly a flat angle, two to five degrees. You pumped ground ore into it with reagents and the reagents would usually be oil—actually often vegetable oil--so they were really fatty acids and they would attach to the sulfide minerals and float to the surface. As the tube rotated at a flat angle so they had a very, very large surface area inside the tube, the sulfides would float and overflow the tube. In probably 1905, something like that--it was one of the early-day flotation processes. It was so early that it predated the first flotation plant in the United States, the Timber Butte Mill in Butte of 1911.

Another good learning experience were field trips. The Tacoma smelter, one of the principal copper and arsenic smelters in the United States, was at Tacoma. They could handle high arsenic ores and one of the principal sources of the high arsenic ores was the Philippines. This Tacoma smelter was at tide water so there were always ore boats from overseas in with concentrates.

Bethlehem Pacific had an open-hearth steel-making operation. There were a lot of brick plants in the area.

One year I was in charge of the senior field trip and so we went over and saw the Kaiser Aluminum plant in Spokane. And we went up to the Nob Hill Gold Mine in Republic, Washington--a very interesting mine. One of our UW graduates by the name of Andy Fergus was on the staff there. He has recently retired from the Bureau of Mines in Albany, Oregon. They had a fascinating thing--the first time I had ever seen it called a Dorr tray thickener and they were using that for counter-current-decantation of gold ore, to separate the dissolved gold in the cyanide solution from the ore which is now impoverished in gold.

And then we went up into Canada to Consolidated Mining and Smelting. Their mine and mill was at Sullivan, B.C., and that was fascinating because they had a 12-foot, 1,000-horsepower fast-running rod mill. It was probably the first one--if not the first, the

second. 1,000 horsepower was massive. Today we've got multiple 6,000-horsepower motors, so we've got mills with 12,000 and 15,000 horsepower. But in those days there was no air clutch or fluid couplings so they had to build the starting torque into the motor. So 1,000 was about as big as they could go, economically. So I got to see that new operation.

They had a heavy media operation in which they scalped off about 20, 25 percent of the gangue and threw it away. They scalped out the coarse sized crushed ore, ran it to heavy media, and threw a lot of gangue away, so in essence they increased their tonnage about 20 percent by a simple expedient.

And then they found a small amount of tin in the ore and so they would take the flotation tailings from lead and zinc flotation and send them to a series of tilting frames and recovered the cassiterite. They had their own smelter there and so they produced tin on the spot. I had also had tin experience at Washington, and using material from dredging at Good News Bay in Alaska. It was not economical, but they did recover gold and tin from that thing.

A couple of weeks after I got to Seattle, it started drizzling. And in Seattle it drizzles from late September to March! And by March I was ready to cut out paper dolls.

Swent: [laughs]

Aplan: I had a fascinating job which kept me fully occupied but if I hadn't had that job I'd have had to climb the walls. It just drizzled--not heavy, just continual. They get about the same rainfall as Boston, but in Boston the heavens open up and down it comes. That's a month worth of drizzle at Seattle. [laughs] But come spring the Seattle area probably has the most beautiful spring weather in the world. You've got blue skies, big, fluffy, cumulus clouds, snow-covered Olympics outboard, the snow-covered Cascades inboard, Mt. Rainier sitting up there 14,000 feet--and they were raising a lot of bulbs. A town south of Seattle called Puyallup was the daffodil capital. And these daffodils would come out, just acres of them. Then you would see acres of red tulips, acres of yellow tulips, et cetera! I didn't have a camera in those days but it was too bad because--oh, it was just a joy to be alive. There were also a lot of good rhododendrons and flowers. I kind of disliked my first winter in Seattle but after that I enjoyed Seattle very much.

Swent: Where did you live?

Aplan: I lived close to the university the first year--just off the university, and the next year a couple of miles away. The first place I could walk to the university and the second place I had almost a straight shot to my office by car.

They had a good football team, and a very good basketball team. At that time there were about 12,000 students. Now I think there are 40,000 but there were about 12,000 in my era. And it was a <u>good</u> experience.

That spring of 1953 I was accepted at MIT as a grad student. Basically I didn't feel I knew enough and I had concluded that there were two schools that I could go to: one would be Utah and the other one would be MIT. And I had always kind of wanted to go to MIT and so I thought I would go there. Joe Daniels at UW was in charge of the undergraduate kind of recruit evaluation for MIT in those days. Then, in every major community around the country MIT had a group of their former graduates who interviewed potential candidates and Daniels performed that function. He wrote me some very good letters. Also Doug Fuerstenau, who had gone back to MIT as a grad student, put in a good word for me. So anyway I decided to go to MIT.

During the summer I went back to Climax and I've already talked about that. And then at the end, so it would be early September, I left and drove back to Boston via Penn State where I stopped off to see Dave Mitchell. Dave Mitchell was a well-known coal preparation man and he had been a consultant--not on coal, but on some of the other things--for Climax, and so I had met him at Climax. So I stopped back here and then I said, "Well, would you fix me up to see a coal prep plant?" And he said, "Yes, I'll call Julian Parton." Well, [laughs] again, what goes around comes around. And so I went over to see Julian Parton at Mahoney City, Pennsylvania, in the anthracite region. So I saw that plant and then I went up to Boston. So this is September '53.

Graduate Student at Massachusetts Institute of Technology, 1953 to 1957

Aplan: This is the MIT segment. I was there from September of 1953 to May of 1957. MIT had a fairly good liaison with both South Dakota School of Mines and Montana School of Mines. And I guess both of those schools in the period—about 1938 to 1965--had sent maybe a dozen students in MIT, a lot of them in mineral engineering but not all of them, and so there was another good connection there.

In Mineral Engineering we had twelve or fifteen students. The section was headed by A.M.--Antoine Mark Gaudin who was called Tony, but we never called him Tony to his face. [laughs] In those days the students and the faculty were two different things. And of course I had an interesting experience, I had come from a faculty and now I was a grad student and that's quite a humbling experience. [laughs]

There were four faculty in the mineral engineering. Tony Gaudin was doing radio tracing, thickening, and he was doing the second edition of his flotation book. There was Phil deBruyn who was doing surface thermodynamics. He came from South Africa originally. There was Dick Charles, R.J. Charles, who did comminution and scale-up of grinding devices, and Doug Fuerstenau. The latter three were assistant profs. Doug did hemi-micelles, electrostatic attraction of collectors and slimes (very fine particles) to mineral surfaces, ion exchange, activation, bubble flow. Doug was an interesting fellow--ideas seemed to flow like sparks from an anvil from Doug. [Douglas Fuerstenau, interview in process, Western Mining in the Twentieth Century series, Regional Oral

History Office, University of California, Berkeley, 2002]

I had known him since 1946, so he used me as a sounding board often. While he had a few ideas not so good, he had about the highest recovery of good ideas of anyone I've ever known. I saw many of his ideas developed at genesis. He received, for example, the Gaudin Award for his work on the electrostatic theory of flotation--well, I saw that at genesis several years previously. A lot of other people had also done work on it, but I knew who did it first by far. It was also interesting to kind of get inside his creative mind. A lot of us, you know, we make three yards a carry, and often we won't make the first down and then you've got to start over again. Doug was very creative and he had a lot of things and all of these things I have talked about turned out to be winners as published papers of important work.

I was a research assistant. I was paid quite well, but MIT had a high tuition. They took most of it back for tuition and in those days--today, students get a waiver on tuition for the tax. We didn't. We paid both state and local tax on the whole smear. So it was a continual money cash-flow problem. And while I had a stash of money, it turned out I didn't have enough. [laughs] There was a lot of thrilling research going on. I couldn't possibly begin to tell you all the things that were going on—but there were a lot. Well, you can imagine with fifteen people or thereabouts, there were a lot of things going on.

Swent: Let me just ask, what was the physical set-up? I'm trying to get at how you were interacting with each other.

Aplan: Okay, MIT. If you stood in front of MIT, they had two big wings with a big domed center section and then they added on buildings in the back. They have since added on more and more and more, but in those days most of MIT was all hooked together. You could walk down the corridor and come to the next department and in the same building. We were in Building Eight. Metallurgy had from the basement to the third floor in this building. And Mineral Engineering was on the first and second floors. And so all we had to do was walk down stairs and we could see all the rest of the group, so we were just in one segment of the building.

Swent: It was easy to run into each other and exchange ideas?

Aplan: And the faculty--their offices were just across the hall or down the corridor or down on the next floor, so everything was fairly close in. There were a lot of good liaisons; I made many good friends from that era.

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Swent: We were talking about MIT and the interchange between scholars.

Aplan: [laughs] Yes, it was interesting. To give you a frame of reference, up until 1950 MIT produced about 80 percent of all doctorates given in metallurgy. Now with the growth of material science and so forth they probably don't even produce eight, but in those days if

you had a doctorate in any metallurgy field, chances are you were an MIT graduate. There were a few other schools turning out one every now and then but MIT had a big operation. And even until Gaudin's retirement in 1965, they were the principal producer of doctorates in mineral engineering and a significant producer of M.S. people.

And they are everywhere. One of the professors at Stanford, George Parks, he was in that group. Professor Ross Smith and Professor Rommie Bautista and Maurie Fuerstenau at Mackay School of Mines in Reno, were out of that group. Jim Brown, who is at Queens, he was in that group, as was Will Freyberger at Michigan Tech. In fact, you can go down the line and identify processing people from that group or their progeny—their former graduate students. For example, Somasundaran was one of Fuerstenau's students at Berkeley and now Somasundaran is at Columbia and one of his students, Brij Moudgil, is running the program at Florida. Here at Penn State, Subash Chander, Dick Hogg, and Osseo-Asare were all students of Doug Fuerstenau, as was Ken Han at SDSM&T, Ed Shall at Florida, and John Herbst, formerly at Utah. Anyway, they are lineal descendants of that Gaudin group. An exception is Roe Han Yoon at VPI.

Swent: Right.

Aplan: I said it was a close, close-knit group.

Swent: Did you socialize together as well?

Aplan: Oh, yes. But again, mostly work.

Swent: Mostly work.

Aplan: And another one that was important is Pete Iwasaki who is at Minnesota. And I've probably forgotten umpteen more. There was some very dynamic teaching.

I've said it was a close-knit group. All of MIT was close-knit, I think because the buildings were hooked together. You just walked down the hall. And in those days if I had a problem that the chemists knew about, say, in organic chemistry, I went down and knocked on the door. And if I had a problem that the chem e's [chemical engineers] knew about, I knocked on the door--or a geologist, or the soil people, I just knocked on the door. And only once did I ever have to wait; they would interrupt what they were doing and help me.

Now one of the advantages of going to a grad school at a very active university in those days was that you could see the big names, talk to them and get help from them, whereas if you're an undergraduate, what difference did it make whether they've got six Nobel laureates? The undergraduates have never seen any of them. But at that place and at that time, you could get to all of the people. And I was able to get help from a lot of really good people. They would take the time to help me, so it was a wonderful thing.

Swent: So they were actually there in their office?

Aplan: Yes, this was before the traveling became so popular.

Swent: That's what I was just going to say--were they doing consulting all over the world?

Aplan: Today just try and find them!

My thesis was on the thermodynamic analysis of adsorption of collectors on surfaces. And the system I used was the mercaptan/gold system. My lead advisor on that was Phil deBruyn, but also Reinhard Schuhmann and Carl Wagner, called Wagner [pronounced with a hard W] because he was from Germany. He was probably the world's most important metal thermodynamicist at the time. And J.Th.B. Overbeek from Utrecht was one of the world's leading colloid chemists. They would all help and that helped me a lot.

In courses I took what I had to and a few others, but I had credit for most of the courses so I would sit in and see how Gaudin did it, and how Charles did it, how deBruyn did it, how Fuerstenau did it; and I learned a lot because they organized it differently than I had done. They had access to more information than I had, they had advantages of interacting with each other, whereas at the University [of Washington] I was by myself. And so they had a lot--and they're probably all smarter than I was, too. In any event, I sat in on courses and I learned a great deal.

And the fact is, when I came here a decade later, it helped me because I kept all those notebooks. And I had seen how they had organized it, what things I wanted to change, but basically I had a framework. They had a lot of good people.

In metallurgy we had John Chipman and John Elliott and Tom King. And they're all well-known slag metal thermodynamicists.

In crystal chemistry and--I minored in geology--and in crystal chemistry was Berger who later became provost at MIT--a well-known crystallographer. Hurley--I took ore deposits from him. I took probably the last practical ore deposits course ever given at MIT; they went off on the science kick after that.

But I had an old-line ore deposits course; I took a couple of courses from R.D. Parks. He had written the book on mineral property evaluation and so I took that course. The course in industrial minerals was taught and I also did some chemistry courses and minored in geology. I did mainly radio chemistry courses, as I was using radio chemistry --I was using sulfur 35--today we're calling it ^{35}S, but in my day it was S^{35}. The 35 is the isotope number.

Swent: Did you have any interaction at all with Harvard people?

Aplan: The only ones I had were in geology. I had to do a fair amount of class reading and I got tagged to work with Gaudin on his book. I was assigned two chapters--he would put the

arm on the grad students to proofread the entire thing, to check out every reference--not only that the reference was valid, but what was said in the text is in the reference. One time, I had to go back and read Plateau in the original over at the Harvard Library. He had done some work on bubbles in 1860 or something--[laughs] so I had to go do that.

At that time Harvard economic geology was winding down, but as you know, in the period 1880 to 1960 Harvard was the preeminent school for industrial geology. In economic geology they had no peer. Many of the classic geologists came out of that group. It was still winding down, but there were a few of them still left. McDonald, who later went to Cal Tech, was there at the time. One geology staff member I remember quite well was Mr. Fletcher. He was a black man who was very skilled at polishing specimens. No one could polish a specimen like he could. And to do any good in microscopy you had to have a well-polished specimen, and to do a good job of polishing you have to know what you're doing. And Mr. Fletcher could do a job that no one else could do and so when I had to do some microscopy for Gaudin's book, I was over there a lot making sure the specimens were right. Then I had to come back and take photomicrographs.

And then we had joint seminars between Harvard and MIT in metallurgy. You could take courses in Harvard theoretically, but practically you would have to have three hours to get over there and back. To walk it took me exactly a half-hour. By bus--you couldn't always trust them and you could get tied up in traffic so you would have to have a minimum of twenty to thirty minutes just to get up there or get back. So you could take courses up there, but practically you couldn't.

I had to do written comprehensives [examinations] in mineral processing and in process metallurgy. And there had been a revolution in metallurgical education of process metallurgy. It had started by some of the people at MIT, namely, Chipman and Schuhmann, probably just before and during World War II and then caught fire all over the country--Utah and Columbia and so forth all got into the act and did a tremendous job. So I had credit for courses on the books but not between the ears and so I had to study fluid flow, heat transfer, and slag/metal thermodynamics. My thermo was pretty weak, so I audited a number of courses, took a couple of courses, and I spent six months studying from eight o'clock in the morning until eleven o'clock at night any time I wasn't working in the laboratory. And I passed the exam. [laughs]

But anyway, I had mentioned that over the years there were about a dozen people each from South Dakota and Montana Tech that had gone back there as students. In my period we had three people from the South Dakota School of Mines who were on the faculty: Walter Rosenblith, who was in electrical engineering--he was an acoustics man--and he later became a provost at MIT; Tom Malone, who was in meteo [meteorology]; and Doug Fuerstenau who was in metallurgy.

Another interesting thing is in those days every other year the AIME annual meeting was in New York City. Then they would go to Dallas or San Francisco or Denver or someplace, but every other year was New York. Today, New York's too pricey, so they don't do that any more. We grad students would take a train down to New York, stay at

the Y [YMCA]. They would waive registration fees, so we could attend the meeting cheaply and learn a lot. It was a good education.

I think it was probably about February 1954 that one evening there was a South Dakota School of Mines alumni meeting and at the meeting was J.V.N. Dorr. After the meeting J.V.N. Dorr invited us over to the Dorr suite--all the various companies, the manufacturers, would have suites where they would have some light snacks and some refreshments. And so here's a man, you know, who had invented the thickener, agitator, and rake classifier, and I got to talk to him. He did all that at Terry, South Dakota, about 1905 and I was too dumb to ask him the right questions that time. I was really in awe of and had a real thrill to be able to talk to the great man.

After four years I had my doctorate. In engineering they gave an Sc.D., so if you see the Sc.D. degree chances are it came out of--they no longer do it. In those days they gave a Ph.D. in science and an Sc.D. in engineering, so if you see a person my age with an Sc.D., it probably came out of MIT. Now some others like Colorado School of Mines give a D.Sc., but we had ours reversed. [laughs] Anyway, after four years I had my doctorate, I was broke, I had a one-year-old child, my wife was pregnant, and I desperately needed money.

Swent: Now somewhere along the way you found the time to acquire this wife!

Aplan: [laughs] Yes, well, she was a teacher in the Boston school system. And when she cashed in her pension, she helped me out of my tuition problem [laughs] and with some living expenses. If she hadn't cashed in that pension we would have been in tough shape, I'll tell you that!

Swent: How did you meet her?

Aplan: I went to a dance one night and I guess that was all she wrote--I was quite attracted--I grabbed hold and hung on!

Swent: Where was the dance?

Aplan: I don't know, I can't even remember. It was someplace over in Back Bay.

Swent: You weren't just studying <u>all</u> the time then.

Aplan: Well, this was on Friday or Saturday night. I never went anyplace other than Friday and Saturday night. And then on Friday and Saturday nights I would go to some jazz joints down—

At the Copley Square Hotel they had a place called Storyville that George Wien was running and he had some very famous jazz players in there. Then down in the basement he had Mahogany Hall in which he had a five-piece, six-piece, jazz band which also had some very, very important jazz players. The trumpet player was Doc Cheatham,

who just died at ninety-something. He was recording up within a couple months of his death, I think. He had just the sweetest tone on that trumpet you ever heard in your life. And then the trombone player was Vic Dickenson who was also well known. The piano was Claude Hopkins, who previously was a band leader, and on clarinet and drums were the two Druten Brothers. Wien was a tremendous impresario--he was the one that started the--down in Rhode Island—The Newport, Newport Jazz Festival.

Swent: Oh, yes.

Aplan: Well, anyway, I got to see all those people. I was able to sit down in Mahogany Hall and nurse a Scotch for two and a half hours. One Scotch. It cost me, I don't know, 35, 50 cents. [laughs]

Swent: But a lot of good music.

Aplan: A lot of good music, but I didn't have any money.

Swent: Does your wife enjoy jazz too?

Aplan: No, well, she said she did but that was fake. [laughter] Also, on Mass. Avenue over by Huntington Avenue there was a jazz joint where they had a lot of New Orleans style jazz. I brought her in there one time--it was kind of a narrow, narrow room and I brought her to sit in front of the bandstand when the deParis brothers were playing. They played trumpet and trombone and they also had a clarinet and a piano and drums which played loudly. And she didn't care for that.

And another time we went to Storyville, which was upstairs in the Copley Square Hotel. By upstairs I mean the first floor. And Ella Fitzgerald was singing there. They had a fairly low-ceiling room and you could cut the smoke with a knife. And neither of us have ever smoked and now when I mention it my wife says, "Yes, I remember that smoke-filled room." [laughter] But anyway.

Okay, there were a number of other kind of goodies. At Tech they had a thing called the Tech Christian Association--TCA--kind of a YMCA type thing. And they could get cheap tickets--two dollars--in the front row of the second balcony for play try-outs in Boston, so we saw a lot of plays.

Swent: They used to try them all out in Boston then.

Aplan: Yes, and I got to see a lot of them for two bucks, or for four dollars total. [laughs] I don't know what arrangement they had but it certainly was tremendous. And in the front row you could really hear everything, but if you're back three or four rows, forget it.

Swent: You had a lot of good theater. Did you ever go to the symphony?

Aplan: Oh, yes. We would go there, but usually for the rush or Pops concerts.

Swent: Did you stay there through the summer as well?

Aplan: Yes.

Swent: So you got in on the Esplanade concerts.

Aplan: I went several times over my four years.

Swent: When were you married?

Aplan: I was married in July of 1955. Our first daughter was born a little over a year later.

Swent: Did your wife continue teaching?

Aplan: She did until she showed. In those days women who were pregnant were kicked out.

Swent: Right.

Aplan: Probably just as well because she went through quite a spell of morning sickness.

Swent: Where did she teach?

Aplan: She taught third grade in, oh, let's see, William Ellery Channing grade school in Boston. I can't remember where it was. She lived in Dorchester at the time, so I used to go Route 3 down to Dorchester. I would go down the river, across the bridge, over at Kenmore Square, and then follow Route 3.

Swent: All right. What was her maiden name? What is her name?

Aplan: Oh, Clare Marie Donaghue. That family is the only one in the Boston directory spelled that way. And yet there are I don't know how many pages of Donahues. She was born on St. Clare's Day. And her birthday is one day different from mine. I was born August 11; she was born August 12. Our oldest daughter Susan was born August 2, our son Peter was born August 10, so at that point I said we've got to fill an inside straight. [laughter] But we didn't. Our youngest daughter Lucy was born in September.

Swent: So the rest of you all have your birthdays the same week! Isn't that interesting.

Aplan: Well, we certainly get tired of cake at the end of that period.

Swent: I'm sure.

Aplan: We also have one of our five grandchildren born in August.

Swent: Oh, my!

Earning the Sc.D., Learning the Procedure of Research

Swent: So you got your doctorate at MIT.

Aplan: I just got my doctorate. Fact is, I left before I had my doctorate.

Swent: I was going to ask if you went through the ceremony?

Aplan: If I had stayed for the official graduation they would have given me a free hood which was the only free thing MIT ever gave [laughter]. Well, they gave me a good education. I was so broke, I took off. As soon as I had the official names on the thesis, I left.

Swent: Finish up just a little bit about the thesis and, you know, the process of getting a doctorate. Was that a tough one?

Aplan: It was difficult because I spent two years getting an experimental system to work. It's fairly easy once you've got the system; then it's a matter of cranking out the data. But I spent a lot of time getting a system to work. I was working on adsorption of mercaptan from both the gas phase and from liquid phase so I had to use different experimental techniques and I had a very difficult time getting equilibrium. Is ten minutes enough? Is an hour enough, is a half hour enough, is two hours enough, etc. And I made the mistake of starting to work with silver--well, silver would reduce some of the sulfur in the mercaptan [laughs] so you had silver sulfite. And so I had a mess with that. I spent months sorting that system out, but I finally got it and once I got it, I would say most of the usable data I had I cranked out in one year. But I was there four: I spent a lot of time digesting the data and I spent two years getting the system to work.

Swent: Whose idea was the topic?

Aplan: The basic idea--there was a paper by Schuhmann, deBruyn, and Overbeek that had shown thermodynamically that the adsorption is greater from the gas phase than from the liquid phase. At least in some systems, there is a stronger adsorption from the gas in the bubble than there is from the liquid onto the surface. Remember, in flotation what we do is attach a bubble onto a mineral where that mineral has first been coated with a reagent we call a collector. I showed that to be true for the mercaptan gold system. A student at Utrecht showed it to be true for another system using a detergent.

Swent: So this was a really key discovery?

Aplan: Well, I don't know if it was a key discovery or not. I guess the thing I learned most about it is in the doctorate you have to use so much other information. While you deal with a narrow subject, you need broad information, so you know, I had to know what was going on from chemistry, I had to know what was going on in chem-engineering, geology, other phases of metallurgy, et cetera just to be able to put that system together. And I said this is where the ability to walk down the hall and knock on the door really came in useful. So

I think I learned more about the procedure of doing research than I did from that particular system by itself. Anything else?

Swent: Well, I wish we could get at the secret of creativity, but I don't suppose it's easy. [laughs]

Aplan: I've concluded that over the years I've encountered only about three very creative people in my life. And I've come to the conclusion that the brain must be like a computer which must be able to sort wheat from chaff, and be able to store information in a manner for simple recall because information may be disjointed and may even come from different technical disciplines to make a whole. I'm sure it doesn't come as a sudden spark, so there must have a unique switching mechanism, a unique storage mechanism, and a unique discrimination mechanism. I'll really remember this and I'll forget about the rest of this junk. I'm sure that you would agree with me that as you grow older you remember stuff that's just pure junk and you forget something that's important, so obviously some of that junk is using up some of the brain's storage area. If we only had a way to, say, void the brain of this interesting but useless information, we would be able to remember more. I think there's a finite capacity in the brain--but anyway, for creative people I've concluded that they probably have a storage, a switching mechanism and a discrimination technique—so they don't remember all that static.

Swent: At this point you were learning the technique of research.

Aplan: I was learning. I was doing a lot of learning. That was a tremendous learning experience.

Swent: Yes, it must have been.

Aplan: And of course it was very competitive. You want to make sure that you succeed and so there wasn't much time for fiddling around.

Swent: Did you have a sense at that time where this was leading you?

Aplan: Yes, I did. And I will talk about this a little later.

Swent: Okay.

Aplan: Many of the things that I've done here at Penn State were the result of things I saw in industry and at MIT.

To give you an example of this, when I first got to MIT, I took a course in radiochemistry because I was going to use radioactive sulfur to measure adsorption. And taking this course in radiochemistry they started describing analytical methods that they used and one of them was a technique called ion exchange and another one was a technique called solvent extraction. And as soon as I heard those, I said, "I know where I can use them; I could use them in hydrometallurgy."

What I didn't know was that Gaudin, who was technical director for the AEC

Winchester Laboratory--originally started at Watertown Arsenal and then moved over to Winchester--was doing that for uranium separation. And today the separation of the uranium from solution is mainly by solvent extraction, but sometimes ion exchange, so the techniques that you saw down in Grants were developed actually at Oak Ridge in chem labs during World War II.

My professor of radio chemistry had come out of that lab--C.D. Coryelle--and he described those techniques in class. As soon as I heard that, I said to myself I could use that in hydrometallurgy. Again, what I didn't know was Gaudin was way ahead of me. [laughs]

Swent: Did you talk about it with him?

Aplan: Oh, at that time it was all secret--he couldn't talk about it.

Swent: I see.

Aplan: That wasn't revealed until 1957 when Eisenhower agreed to release technical data from the atom bomb program. Well, you know, ancillary data--

Swent: Right.

Aplan: Not plutonium or anything like that, but ancillary data. This was done in a conference in Geneva in 1957--so that was the first I definitely knew about it.

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Swent: One of the people that I've interviewed is Wayne Hazen, a key person in that. [Wayne C. Hazen, *Plutonium Technology Applied to Mineral Processing; Solvent Extraction; Building Hazen Research; 1940 to 1993*, Western Mining in the Twentieth Century series, Regional Oral History Office, University of California, Berkeley, 1995]

Aplan: Very much so. He was important as was Bruce Clemmer over at the Salt Lake [U.S. Bureau of Mines] Station to the uranium industry. Those two were very important. And Wayne actually for years was selling the concept of a chemical smelter. He had that idea when he started Hazen Research.

Swent: A chemical smelter.

Aplan: Yes, where you do everything in a solution rather than pyrosmelting that was being done.

Swent: It all intertwines, doesn't it?

Aplan: Yes, yes. Okay, want to go on to Kennecott?

Swent: Well, if you're ready. Do you think you've said all we need to about MIT?

Aplan: Well, it's all I've gotten written down, so that's it. [laughs]

Swent: Well, okay. Maybe you'll think of more later.

Aplan: Oh! There's one other thing I thought I might mention. In those days before I got married I ate meals in the graduate house. But you got tired of that after a while and so I would eat breakfast and lunch and for dinner I ate out. Boston had a rule that there was a tax if the meal cost over a dollar, so there were a lot of $.95 dinners and so we would go to get spaghetti dinners. There were a number of pretty good restaurants up in near Harvard Square--whatever that street that Radcliffe was on. It was just across Mass. Avenue from Wendell Street. Up there was a good little restaurant. Also, there were a couple of good restaurants over in Back Bay. I could just walk across the bridge and get there easily or one of us would drive. And so we would eat these $.95 meals that were pretty strong on the bread but awfully cheap. [laughs] And then on Saturdays I worked in the lab in the morning and then I would go to Durgin Park and, again for $.95, get the protein ration for the week. They had very generous helpings of pot roast and pork and whatever.

Swent: That was quite a place.

Aplan: It was and still is. And every time I go back to Boston I go to Durgin Park. Excellent cornbread. I've got the recipe, but I can't make it like they do. I try and try and try, but they really did a tremendous job. And one time a friend came and took me out to dinner and for about two dollars bought me the prime rib and that filled the whole platter, but I never had money enough to do that on my own. After that meal we would walk up Washington Street to a subway--usually around the Winter-Summer Station and pass by the several discount clothiers over there and see if we could get something cheap. The criteria of merit was cheap! I got a couple of pretty good tweed jackets and a slate gray suit to be in the proper uniform.

Swent: You must have had quite a time to support a family at this time.

Aplan: Well, I did afterwards when I got married. I ran out of money just shortly after I got married. And my wife was always impressed that I spent my last dime on a diamond ring for the engagement. [laughs] She didn't know that at the time, but I blew the entire wad. It turned out to be a good diamond, too. That was a good purchase.

Swent: You still have the same wife, too.

Aplan: Yes, that was an even better purchase! [laughter]

Swent: That's even better.

Aplan: And she got me through the school.

Oh, there's one thing I should mention. We first lived up in Harvard Square in

Wendell Street--past Harvard Square. I would walk through Harvard Square and get the bus down Mass. Avenue to MIT. But that cost eighty-four bucks, so that was a lot of money. When my wife got pregnant I could then get into the student housing. And they had a bunch of former navy barracks called Westgate West--it was on the Charles River. There was a great big playing field where MIT had these old navy barracks. They had ten apartments in each building--five up and five down--and it was a big fire trap. It was a rabbit row, since every woman in our barracks was either pregnant or had a child under one year except two: one had neither and the other was both. Then later Clare joined the both category. [laughs] But I could get in for $37.50 a month!!

Well, across the street was the Wilson Packing Company. Their rendering works was a separate entity called John Riordan & Sons. That was the rendering works and it stunk. But, gosh, you know, $37.50. So it was wintertime when we moved in. After it warmed up a little bit my wife said, [sniff, sniff] "What's that?" And I said, "I don't smell anything." [laughs] I finally had to admit that that it was a rendering works. On the luck of the draw we got the building right close to the rendering works.

Swent: Oh my!

Aplan: Maurie Fuerstenau, who was also an MIT grad student, lived close to the rendering works, too. The women didn't like that smell so they somehow found the unlisted number for John Riordan & Sons. They would call that number and complain, and the person answering the phone would say, "Okay, we'll put in the control, okay?" Years later I ran into a student who had been at MIT and used to work in that plant on night shift. He said when they got the call they went over, they opened up the furnace, and threw in a cup of water. Then there was a puff of white smoke. [laughs] And that was the control! [laughter] So it was a psychological pollution control.

Swent: Oh, dear.

Aplan: We had a good time. I was about the only one in our barracks that had a car. So we would load up the car and go up to Crane's Beach, north of Boston, or occasionally we would go down south to Duxbury or someplace.

But it was a pretty good time. Again, it was done on weekends. One more thing is that since everyone was broke (there was one guy whose mother was quite rich, but she kept him on a short leash so he was in the same boat as the rest of us), there were no problem of green eyes and so forth and you learned to make do. Actually it was a good time of life.

V KENNECOTT COPPER CORPORATION, 1957, UNION CARBIDE CORPORATION, 1957 TO 1967

Research Laboratory in Salt Lake City Serving Five Divisions

Aplan: Okay, Kennecott Copper Corporation: May of 1957 to December of '57.

Swent: How did you get the job at Kennecott?

Aplan: I applied. You know, you hear about them, and I applied. I liked that job because they had a new research lab at Salt Lake.

Swent: Do you recall how you heard that it even was available?

Aplan: Probably through the grapevine.

Swent: I was wondering if your professors had been in--

Aplan: Well, probably through Gaudin. Gaudin, you know, used to be at the University of Utah until '32, I think--from '26 to '32 or something like that.

Anyway, they had just built this new building at 1515 Mineral Square just across from the main campus at the university and less than a block from the Mines building so it was close in. There were some excellent people there. In ore dressing there was Art Last.

Swent: So this was in Salt Lake?

Aplan: Yes, at Kennecott Research Lab, at Western Mining Division's research lab. Johnny Prater was in hydrometallurgy, and was Ed Malouf who did much of the engineering for the bio project--Kennecott was the first one to make use of bio-leaching. He won the Douglas gold medal for that among other things. A guy by the name of Mark Tuddenham who handled special projects, and in geology and mineralogy, was Ron Woods.

A guy by the name of Glenn Buergner--Buergner was interesting. During the thirties the Bureau of Mines had done some classic work on ore microscopy applied to mill problems. [This was] done by Head and his associates and one of his associates was Glenn Buergner. I found out later--many years later--he was a Penn State graduate. And then later Slim Thompson was in geology-mineralogy and I would work later at Carbide with Slim Thompson. Again, what goes around comes around.

At that time this lab did two main things; one was service work for the divisions. At that time Kennecott's Utah division was there at Salt Lake, or just south of Salt Lake--the mine, and the smelter, and a little later a refinery. They had the Ray Mines division in Ray, Arizona; the Chino division in New Mexico, not far from Silver City, New Mexico; and the Nevada consolidated division in the Ely-McGill area. The smelter was in McGill; the mine at Ely. And then they had a very, very aggressive exploration group called Bear Creek Mining Company. You'll find half the older geologists in the United States are alumni of Bear Creek.

And so we did exploration back-up for them and I also worked on a columbium project. They had the mineral pyrochlore--it would be a calcium, Cb_2O_5 and then a third position of either fluorine or hydroxide. And they had a big deposit of that at Oka, Quebec. A lot of people were working on that deposit but Kennecott had one big piece of it and we were working on that.

Salt Lake was a good shopping town. We had been poor graduate students and we had quite a few things we needed and I suddenly had some money.

Swent: How much were you paid?

Aplan: Seventy-two hundred bucks.

Swent: An annual salary?

Aplan: Annual. It was a lot better than $208 a month, I'll tell you! And better than at University of Washington where I think I got $4,500.

Swent: Well, a doctorate counts for something--and it should.

Aplan: And then we bought a clothes-washer; we had to buy clothes.

Swent: You had two children by now?

Aplan: Our son Peter was born in August of '57.

Swent: I see. What benefits were there then? Insurance?

Aplan: The medical insurance was through Blue Cross. I had a little problem because I'd been in Blue Cross in Massachusetts and Clare was pregnant and I had to do a lot of talking to get

them to transfer from the Massachusetts Blue Cross to the Utah Blue Cross. But anyway, that's what Kennecott used, was Blue Cross, so that was very helpful, particularly since I would have a new child.

So Peter is an LDS baby--he was born in the Latter Day Saints Hospital, which was an excellent hospital. My wife had a tremendous pediatrician there--or OB doctor--and it just was tremendous. In those days a husband couldn't get into the delivery room but you could get in the waiting room before she went into the delivery room; other hospitals wouldn't even do that in those days. Husbands stayed in the waiting room the entire time. When my first child was born I was downstairs the entire time. I took her in and that's it. This was at seven o'clock and the next thing I knew at eleven o'clock the doctor said, "You've got a baby girl." "Okay."

Clare still thinks a lot of that LDS hospital.

One thing about shopping in Salt Lake: several of the stores had really quality merchandise. In the first place, Z.C.M.I.--Zion's Cooperative Mercantile Institution--the Mormons' general store, was downtown, had a parking lot right to it, you could go to that parking lot, walk right in the building and get what you want--they had everything in that building. Wonderful. We bought a kitchen table and chairs in Salt Lake and we still have them in the kitchen. Yes, it had good quality merchandise. And you saw a lot of that in Salt Lake. It also had some excellent restaurants--cheap, which is amazing because, you know, [laughs] there was no drinking at any of those restaurants and so they had no bar to subsidize the restaurant operation. They still had excellent restaurants there. They had one called Bratton's Seafood Grotto. We would get there maybe on a Friday and it wouldn't cost much--amazing.

Swent: Where did you live?

Aplan: I first lived on Yale Avenue, not far from that big park that was there. Unfortunately, this was on Yale below the benches so it was a lot hotter down in the hole. The cool places in Salt Lake are up on the benches--you get nice, cool breezes at night. I didn't have that. I had a nice brick house, though, and a good landlord. And Salt Lake was an extremely clean city.

Swent: Still is.

Aplan: I know, with those wide avenues and stuff like that. The numbering system took a while to get used to. When I came into Salt Lake the first night in the dark we had arranged for a motel, I think, on Third. After I passed my third Third Street--

Swent: [laughs]

Aplan: There's a Third South, a Third North, a Third East--a Third West, somewhere and I was totally confused. Anyhow, I finally found the motel. And once I got onto their numbering system it worked out very nicely. It's easy to get around Salt Lake.

Swent: How much did you pay for rent, do you remember?

Aplan: About a hundred bucks.

Swent: For a house.

Aplan: Yes, well, they also had an apartment in the basement. I had the upstairs. It was about a hundred, I remember, because my first check to the landlord bounced.

Swent: Uh-oh.

Aplan: I made a mistake in the checkbook and I was still using the Harvard Trust Company and he came--"Oh, oh." Fortunately, I had just been paid and I was able to pay him, write him a new check. I was using Walker Bank downtown and he was able to get his money right now. [laughs] But that was embarrassing.

Oh, and the other thing was on weekends we would go up toward Alta or Brighton or something like that. You would drive up those canyons where it was nice and cool up there.

Swent: Were you skiers?

Aplan: No. My wife couldn't have skied anyway.

Swent: No.

Aplan: When I was in grad school I sat there for four years with ideas that--here's the things I would like to do: I would like to do some work on grinding--the bottleneck in any milling operation is the grinding operation. About 60 percent of the costs are there, too. If you want to mill a ton of ore, typically, say, in a copper concentrator 60 percent goes into crushing and grinding, so I wanted to work on that. I had some ideas on locked particles--in other words, it's part copper and part gangue and you have to separate the two one way or another so you end up with a copper concentrate and a tailing you throw away. And flotation rate is an important parameter. Different minerals float at different rates and so you can use this sometimes to separate one from another. And I tried selling those ideas, but the lab director had his own ideas about what was needed and none of them included those concepts. [laughs] So I decided I wanted something a little more challenging so I went out and started to see what else was out there.

I ended up with three job offers. You could get a job pretty easily, so I easily came up with other jobs. But we made quite a few good friends there at Kennecott and in that short time I learned quite a bit, so I don't consider it a loss.

Swent: How long were you there?

Aplan: Well, I was there from May to December. So it was seven months. And then I loaded my wife and children on the plane and I drove back East with the back seat full of our possessions, except those that went on the truck. Anyway, I ended up with offers from Union Carbide, American Cyanamid, and the University of Minnesota.

I didn't take the Minnesota job, but it was kind of an interesting experience for me. Let me digress a second--they were looking for an assistant director in their Experiment Station. E.W. Davis, who was the great man in taconites--he was "Mr. Taconite"--had retired and his assistant Henry Wade had taken over. And Wade was only a few years from retirement and so they were looking for recruits. Also I would have had an associate professorship in the university. And at that time S.R.B. Cooke was there at the university so they had a good program both academically and in the Minnesota Experiment Station, at that time the best state experiment station in the country by far. Davis had done all this experimental work, so when it came time to put in a taconite concentrator in the fifties and later, he had all the technology on the shelf--the magnetic separators, the agglomerative techniques, the whole bit. So he was a great man in our profession.

Swent: That was when the taconites saved the day, wasn't it?

Aplan: Yes, yes. And that was E.W. Davis who was out of the University of Utah. In the teens he had gone to Minnesota, developed these concepts and he had to keep the faith for decades before it paid off. But it paid off, paid off big. And so I went up there and interviewed and in the interview I had to give a lecture and so the only thing I had was my thesis--which had been a thermodynamic study of adsorption at interfaces. I walked in to give that lecture and I looked out in the audience and there was Peter Debye, a Nobel laureate in chemistry. He was one of the major people in the Debye-Hückell theory used by physical chemists. I had seen him before many times. He had been a visiting professor at Harvard; I didn't know him; but I knew of him during that era. And I went in to lecture and I was thunderstruck--what does this little boy do with this great man? And I had to make use of the Gibbs-Duhem equation and I got up and I said, "Now we're going to use the Gibbs-Duhem equation," and I got up and grabbed a piece of chalk, went to the board and my mind had a total blank. I felt like it was about an hour; probably it was a few seconds. I turned around once and went back to the board and wrote it down. [exhale] I got a job offer at the end of it so [laughs] I was pleased about that. But didn't take it and didn't take the job at Cyanamid either. I took the job at Union Carbide.

Research Engineer, Electrometallurgical Company, Foreign Mining Division

Aplan: It was the Electromet [electrometallurgical] division and it was nice because I ended up with a 39 percent salary increase. They paid 10,000 bucks.

Swent: Well!

Aplan: So I was in hog heaven.

Swent: Where did you interview for that? In New York City?

Aplan: No, at Niagara Falls. They had a large research lab in Niagara Falls.

Union Carbide, in the decade I was with them, loved to reorganize, so I joined Electromet--it was called Electromet Company--Electrometallurgical Company, was the proper name. And over the years that was changed to the UC Metals Company. Then I worked for the Union Carbide Ore Company, then for the Union Carbide Ore division, then for the Union Carbide Nuclear Company, which was a domestic mining subsidiary--the ore company was a foreign mining subsidiary; the Union Carbide Nuclear Company was a domestic mining subsidiary--then I worked for Union Carbide Nuclear division, then I worked [laughs] for the Mining and Metals division. And all the time I was at either Niagara Falls or Tuxedo, New York. They kept changing the title.

My main job was to work for the Union Carbide Ore Company, which was the foreign mining subsidiary. Now I would be loaned at various times to domestic metals division or the domestic mining subsidiary but my principal job was with the foreign mining division. The director of research for the Ore Company was Rush Spedden--again, we've talked about him from the University of Washington, and he was also at Montana Tech, and at MIT, and then he joined Union Carbide, and then later he went to Kennecott, so you notice how all these things connect. He was an excellent boss. He would support you, he would leave you alone, but you had better produce and I liked that. I was willing to produce--

Swent: What was your job title?

Aplan: Well, I started out with Union Carbide as a research engineer. Later I was promoted to section leader, and then finally was the group manager of mineral research.

Swent: How many research engineers were there?

Aplan: A lot. At different times there were a lot. When I first joined them the minerals and chemical engineering division alone had twenty-seven people and that wasn't the biggest group, but I'm talking twenty-seven staff people. They had some really classy people and I'll talk about those in a couple of minutes.

Swent: I was just trying to get a sense of the size of the organization.

Aplan: It was big.

Swent: What sort of building?

Aplan: They had a couple of buildings. They had about 200 technical people there so it was a big operation.

Swent: Were you in separate little alcoves? You had offices?

Aplan: We had separate offices.

Swent: With doors?

Aplan: Yes, you might have a roommate or might not, depending.

Now, Spedden is interesting because I knew his father, Henry Spedden, from Seattle because he associated with mining people and so I met him through the mining group in Seattle.

Swent: When did you join AIME?

Aplan: Oh, I'm a fifty-year member so I joined in 1947.

Swent: You mentioned going to the meetings in New York City, but you had joined before that.

Aplan: I joined as a student.

Swent: At Rapid City?

Aplan: At South Dakota, yes, Rapid City. And the fact is I didn't get around to doing it until January of 1947 and Doug had done it in the fall of '46 so Doug was a fifty-year member before I was, even though he's five years younger than I am. [laughter]

Swent: So you were attending the AIME meetings all this time, I guess?

Aplan: Well, no. I mean, you had no money to go to them.

Swent: Well, but were there local sections?

Aplan: Oh, yes. For the local sections, yes. And they had very good local sections. In those days there wasn't a split between the metallurgical society and SME [Society of Mining Engineers] so that was run as one unit.

But the interesting thing about knowing Spedden's father and being at all the same places Spedden has been, though often at different times--I have found that in the mining community you can go to a meeting either in the States or overseas and you may not know a soul in the room, but you go up and start talking to someone and within a couple of minutes you have some connection. You have worked at the same place at some different time, you had a friend that works there, or he had a friend that worked where you have worked or something, but you have some relationship with him. And so I've always found it a very nice, friendly, close-knit society and I've been extremely proud to be in this profession because it has a lot of camaraderie in it.

Swent: Yes, it does.

Aplan: Carbide was a major producer of manganese, chrome, and tin through the foreign mining subsidiary and of vanadium, uranium and tungsten through the domestic mining subsidiary. We had operations in Ghana; Rhodesia, which is now called Zimbabwe; South Africa; Guyana, which used to be British Guiana; New Caledonia; Thailand. In the U.S. we had mining operations in Colorado, Utah, Wyoming, Texas for vanadium and uranium; Arkansas for vanadium, California for tungsten, Nevada for tungsten, California for asbestos, and we had an active overseas exploration group.

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Carbide through their ore division had an international exploration group and I worked as back-up. In other words, they would find something and, say, within three weeks we would have to know whether to pick up the option or not. Can we process it? And so it was up to me to say yes or no or to try or whatever. And sometimes I had to go into the field. And we'll talk about that later.

Swent: So they actually just sent you a physical sample that you--

Aplan: They would typically airfreight in a sample.

Swent: How big a sample did they send?

Aplan: Oh, sometimes it would amount to a hundred pounds, sometimes it would amount to a couple tons.

Swent: Oh!

Aplan: They had an active program in manganese, in chrome, columbium, tin, rare earths, lead-zinc, moly, copper, silver, apatite, zeolites, barite, asbestos--you name the commodity and I have probably worked with it at one time or another.

They had some really good people as geologists: people like Art Hueck, Harry Abendroth, Graham Nelson, Dick Claus, Ted Eyde, who now has his own company down in Tucson, John Straczek, TS Ary, who later was head of the Bureau of Mines in the United States--

Swent: And you don't put a period. He's particular about that. It's TS with no period.

Aplan: Right. And then they were supervised by Dean Frache, and John Warde. Warde was a graduate of Montana Tech, though I didn't know that until he had retired.

I was in Niagara from 1957-59, then moved downstate to Tuxedo, New York, which was about thirty-five crow miles from Times Square, but in rush hour it may take

you close to two hours. And then I was moved back to Niagara again from '66 to '68, so I was in Niagara two times and in between I was downstate.

At Electromet, when I first got there it was an excellent laboratory. I guess there were close to 200 technical people. It was probably the world's best post-graduate school in the field. Doug Fuerstenau was there, as was Ernie Peters who was one of the best academic hydrometallurgists on the North American continent. He just retired from UBC. Tom Henry who was later with the Bureau of Mines was there.

Bill Krivsky who invented the argon-oxygen decarburization process was there. There was a very tricky method in order to take very high carbon ferrochrome which ran about 8 percent carbon and convert it into something that contained about a tenth of a percent carbon. The problem was that you use chrome in stainless steel and you usually put it into an electric furnace and you add a ferro-alloy. Now if that ferro-alloy contains carbon it is going to put carbon into the steel, and to get it out you have to blow it out, and if you blow it out you oxidize some of the chrome and of the nickel and put them into the slag; you don't want to do that. So he came up with a tricky method using an argon technique of taking that ferrochrome and making high-carbon ferrochrome into low ferrochrome.

The alternative processes are extremely expensive. One process involves a refurnacing--everything is refurnaced several times and it's a mess. And another one called the simplex process is a long, drawn-out thing. Krivsky solved that whole problem in a small vessel in a short time.

Then there was Bob Hard, who later ended up with Kweckie-Berylco. Obviously they did beryllium and they also did a lot of other elements. And George Healy, who with Hilte wrote many of the classic papers on chrome metal/slag thermodynamics. So anytime you're using chrome you go through Healy's work. Healy later ended up as a professor here at Penn State in metallurgy. And after he retired--we required retirement at sixty-five in those days--he went out to the University of Utah and was a professor out there for about a decade.

Oh, and there was a guy by the name of Jim Downing who's a well-known metal thermodynamicist. And then when I came back the second time, working for me, among others, I had Ron Roman, Stan Rickard, Vic Hoffman, and Tim Todd. And these people have all done extremely well in the industry.

The Sterling Forest Laboratory at Tuxedo, New York

Aplan: I then was moved down to Tuxedo, New York. This lab was called the Sterling Forest Lab. When Harriman made his money as kind of a robber baron in railroads, all the older robber barons looked down on him and they wouldn't let him into Tuxedo, which was the

first cool place out of New York. That's where the rich lived, in Tuxedo. But Harriman was nouveau riche and so they wouldn't let him in though the rest of them had gotten their money the same way Harriman did though he did it a generation later. And so he said, "Okay," and he went up and bought all the land around them. He bought from the New Jersey border north to a town called Monroe. So this thing was about in the greatest part, maybe twelve, fifteen miles long and in depth running from maybe two miles to five miles all the way from Route 17 over to Greenwood Lake--he owned that whole thing.

And then he went over on the highest ridge to the east of there and built two houses, one for Averell and one for his brother. The one for Averell has been given to Columbia University as a conference center and it's just a magnificent place. And now he could look down his nose on the Tuxedo people. [laughs]

In the fifties, Harriman sold that land to City Investing who then had the concept of going to be a big research lab complex. Well, they got in just a few companies, one of which was Carbide and then that thing kind of collapsed. Anyway, now it's been sold off for various housing and so forth.

But there was this forest primeval--I've seen big diamond-back rattlers, not these little things you see out West, I mean we're talking a big one! And copperheads, right on our property. So we had a property in there, Inco had a property, and one of the chemical companies had a property in there. And so Carbide had the lab in there.

We had some very, very good people at that Tuxedo lab. One was Bob Woolery who was a Berkeley graduate under Lyle Shaffer--if you remember Lyle; he was a professor of mining at Berkeley for a number of years. Then Bob Woolery worked for Carbide's Bishop operation and then was transferred back to do ore dressing at Tuxedo Lab. Bill Dresher, who was later dean at Arizona and then headed up the Copper Research Institute in New York. Wayne Naumann, who was a physical chemist, quite well known. The geologist was Howard Jaffe, who had worked for both the USGS [United States Geological Service] and the Bureau of Mines. Jaffe was unusual; he probably had 600 mineral specimens under total recall under the microscope. He could look down the microscope and tell you what that was.

Swent: Oh, my!

Aplan: Outstanding. And then working with him was Fred Mumpton, who was a Penn State graduate. And when I start talking about some of our research, I'll talk about Fred again and Slim Thompson, whom I'd known at Kennecott. So again, round and round and round it goes.

I had a couple of technicians working for me. One was Gene Laur, who had been a technician at Niagara and who we plussed to a junior engineer and took him with us. Gene did a wonderful job but he belonged to the naval reserve and he was in a flight crew--not a pilot, but in the flight crew--and he went off to the naval reserve one summer and they flew that bomber into the lake. A night problem; they were on the surface of the lake

and pulled up quickly and cracked that thing in the middle right where Gene sat and so that ended Gene.

And then I got another technician by the name of Bob Kronkhyte, who was just a local boy who was working as a service repairman for washing machines and driers and stuff like that but he really produced for us. And when Carbide opened up its asbestos plant at King City, CA, he went as a shift boss--and he later ended up as a vice president of a small company and unfortunately died of a heart attack at about fifty-five.

Swent: Oh, my!

Aplan: But anyway, I had the chance of working with some real first-raters there.

Oh, another one I should mention is--working as a development engineer for the Union Carbide Ore Company, mainly for the foreign properties, was Bob Shoemaker, who later became president of SME and has now retired at Grass Valley. And as you remember Bob was the one who finished up Frank McQuiston's oral history. [see ROHO oral histories with McQuiston, Shoemaker] Again, it keeps going round and round in this mining community.

Research on Chrome

Aplan: Let me talk about some of the major projects I worked on in that period. I've already told you that I started as a research engineer and then I was section leader and ended up when I came back to Niagara Falls as group manager. I guess the first thing I'll talk about is chrome.

The mineral chromite, if you look it up in a book, it says MgO Cr_2O_3, but in reality, calcium and ferrous iron--Fe+2--can substitute for the magnesium in the crystal lattice. And for the chromium you can substitute Fe+3 or aluminum +3 or silicon +4 into the crystal lattice, so it's a garbage-heap mineral. On a world basis, the lowest alumina content--Al_2O_3 content--I've ever seen in a chromite is off the flanks of Mt. Kilimanjaro in Africa--and don't ask me how to spell Kilimanjaro--and that runs maybe 3 or 4 percent Al_2O_3. And they get over 30 percent in chromes out in the Philippines, so depending on where you get the chrome, the aluminum content can vary greatly and also the iron content can vary greatly.

Now Carbide used the high alumina content chromes for refractory brick. If it has a good chrome-to-iron ratio--about three to one--and has a chrome content pushing 50 percent, you use it metallurgically. You want that high chrome-iron ratio because much of the iron is going to end up in the slag and you don't want much going to the slag when you make ferrochrome. You always have enough iron to make the ferrochrome, but if you have extra it will go to the slag and why melt up something to throw it away. So you want

it fairly high in chrome.

And about as high as you'll find commercially is around 50 percent Cr_2O_3, so our geologists looked all over the world for chrome and we had active mines in Rhodesia, in South Africa, and in New Caledonia. If you look on a world basis, most of the chrome is found between the Tropic of Cancer and the Tropic of Capricorn, or in countries where at sometime in geological time they were in an environment like that.

Russia had a lot of good chromes and sometimes we could get that chrome and sometimes we couldn't depending on how the politics were going that year. And so our geology group went all over the world looking for chromites. So I've evaluated a lot of chromes from over the world and how to improve them, et cetera.

Oh, and I should mention that if it had a poor chrome-iron ratio--less than 2--typified by the South African chromites, it went into chemical grade. They would use it to make dichromate and eventually end up making, say, chrome chemicals out of it. The metallurgical chrome ended up as stainless steel.

Research on Manganese

Aplan: Okay; the other thing we worked on was manganese. We had operating mines in Ghana, and this was the black MnO_2 and the mineral was a unique one called nsutite. The property at Ghana was at Nsuta. And this is the good stuff for a battery. If you've ever taken a dry cell and torn it apart--this is back in the days of the regular batteries, this is before the new alkaline batteries--but in those days they had a carbon electrode in the middle, it had a zinc casing on it, and it was filled with this black MnO_2 with a sal ammoniac solution--not a real solution, the electrolysis occurred in a kind of a paste.

And this nsutite was very hard to find on a world basis. We were running out of it at Nsuta, so we had to look for another deposit. Our geologists ran all over looking at deposits of manganese that we might be able to process and pull out a fraction rich in nsutite. They found a good one in the Comilog deposit in Gabon. U.S. Steel had it and we were able by heavy media processing to extract some good battery-grade out of it. The reason we wanted battery-grade was because National Carbon Company which was another Union Carbide company made Eveready Batteries and so they were looking for battery-grade. Well, they didn't handle that very well politically because we gave U.S. Steel all the data of where the good stuff was and they said thank you and did it themselves. So between corporations it's not all lovey-dovey.

Swent: Oh! How did you find out about this?

Aplan: From our geologists.

Swent: But how did you know about this political thing? Were you involved in any of the--

Aplan: I was peripherally involved.

Swent: Did you ever go to any of these places?

Aplan: Yes, and I'll talk about that when I get to that.

Swent: All right.

Aplan: The field geologists, John Straczek and Abendroth and that group, those guys were world-based. They were on the airplane all the time looking for stuff. Also at Nsuta, they had an interesting deposit of mangano-dolomite.

Swent: What was that?

Aplan: Dolomite is a calcium-magnesium carbonate. And at that deposit manganese would proxy in the calcium-magnesium position. And so we had one that ran about 30 percent MnO_2, but if you ran it through a kiln, to drive off CO_2, you increased the grade. And we had a plant in Newport News to process that, but it turned out to be inadequate economically.

Our geologists ran into some metallurgical-grade manganese in Guyana. At that time it was British Guyana. In South America on the north coast on the extreme western flank of Guyana was a place called Matthews Ridge. It was so far west that it was almost in Venezuela--not quite. Now to get to that property you had several choices. One, you could go to Georgetown, Guyana--and incidentally, going to Georgetown you always arranged to go in through Port au Spain and you always arranged that you had to stay over a day or two in Port au Spain.

Port of Spain was a wonderful town. It had excellent steel bands. It was just a wonderful place. And then you could go across the island to a bay called Maracas Bay, which was a beautiful beach and except on weekends you could have the whole thing to yourself. I guess it's more crowded now, but it's still a magnificent beach. Or you could get a DC-3 and fly over to Tobago which had a lot of excellent beaches.

Hilton had just built a new hotel in Port of Spain. It was an upside-down hotel. It was on a hill and so you came across a bridge and you took the elevator down to your room. It overlooked the park where they had both a zoo and a park. The hotel Hilton managed had beautiful tile work, but Hilton had managed to get the Hilton H into every damn thing he could. There were beautiful bougainvillea planted there and it was just magnificent.

Swent: Oh, it sounds lovely.

Aplan: On the upper part was the regular part of the hotel and it was several stories high. And they would often have a steel drum playing out by the pool--steel drum band--and in the

bar club operation they would have famous people like, if you have studied calypso, Sparrow is one of the principle calypso singers--he's still around, but Sparrow was something else again. I ran into a man from Cleveland-Cliffs while Cliffs was building a plant in Trinidad and I mentioned Sparrow and he said, "I just heard him last week." [laughs] He's a wonderful calypso singer. And they had steel drum bands all over the place.

It was interesting to see them tune the bass drums where they used a fifty-five-gallon drum and on the head of the drum they would chisel spots and tune them to get different notes. They would only have about three or four notes on a big fifty-five-gallon drum--the bass notes. And I saw them tuning it one time. They used a wooden 2x4 and they hit the thing to tune it! [sings] Hmmm, whang! Hmmm, whang!

Swent: Oh, my! [laughs]

Aplan: Those steel bands are something else again. And one time I was down there, probably about the second week before Christmas, and I was sitting by the poolside here in the tropics, and I'm not thinking about Christmas in the tropics--I'm thinking of snow when I think of Christmas--when I heard a tune and I said, "You know, I've heard that tune before. What is that?" And I listened and listened and I finally figured out what it was. They were playing the "Gloria" on a steel drum band!! Those guys could play anything! And if you didn't like the band they had at the Hilton Hotel, you would go downtown and hear all the steel bands you wanted to!

Swent: You must have loved that!

Aplan: So we had to always make a stop in Port au Spain. Georgetown wasn't much. Among other things, as soon as the British left, the two main ethnic groups were the blacks and the Indians--the Hindu Indians. The minority Ameraindians and the mixed race--largely Portuguese, but all kinds of other combinations, every combination you want--kind of stood off on the side and said, Let us know how it comes out. But those two big ethnic groups would go after each other--burn down each other's villages--. And the first time I went down there in about 1960 it was okay, but later, things got tough. I originally stayed in the Park Hotel, one of these big old wooden English hotels. If you saw one of them you saw them all. They had the same architect, I'm sure, do them. You would see that same type of hotel out in Malaysia. Guyana had another one called the Tower Hotel--it was built out of concrete block--and so I moved into the concrete block one [laughs] after they had a big riot and a fire about two blocks away from the Park Hotel.

Swent: Oh, my!

Aplan: I moved out.

Swent: You mentioned indians--Ameraindians?

Aplan: Ameraindians. American Indians, natives. It isn't a tribe, it's a designation.

Swent: Right, okay. Ameraindians as opposed to East Indians; I see.

Aplan: Right; and the rest were the East Indians. At that time Cheddi Jagan was their leader.

Swent: Oh, yes.

Aplan: Okay? And Forbes Burnham was in charge of the black faction and they were having at each other. I didn't want to be in the middle.

Swent: No.

Adventures in Guyana

Aplan: And so you would usually have to stay overnight before going to the mine. You had several ways of getting into the property. One is you could fly. B.G. Airways had a number of old Grumman Geese and you could fly a Grumman Goose that would land in the river. And then you took a launch about two hours up the river, and then you rode about thirty miles of narrow-gauge from a port called Port Kaituma up to Matthews Ridge.

The other way you could go is you could take the ore boat. If you were going out on the ore boat--from Port Kaituma they loaded the ore boat and it went down the Barama River. It was dredged for the upper ten miles or so and so the ore boat had to go slowly. They couldn't use the rudder, they would steer by hitting the left screw or the right screw. They were just a few feet from the riverbank though after ten miles or so, the river widened out a little bit.

As they tried to go around the corners they would hit the bank. The ore boat had been an old Esso tanker—a small tanker. They could load about 2,500 tons of ore on the boat. And they had two boats one coming and one going, so they had dredged out a place where the two could pass. But in the meantime they would hit the bank and occasionally, you know, if there was an ant nest on one of the trees or a wasp nest it came on to the boat, too. What they had done with the railing, was to move it in about three feet from the edge of the boat. So the railing wasn't on the outside of the boat; it was about three feet in. And it was always bent. As they went around a corner, they would hit a tree or something. While in a temperate climate you had the V profile to the river, in the tropics you had the U profile, and the bank is merely where the mangroves quit growing. The bank dropped off very precipitously into that river. So they had to move the railing in, and even then it was all bent up.

Swent: From trees that would hit it.

Aplan: In the upper reaches of the river the boat displaced so much water that a wave of water

went ahead of the ore boat. And so they had a launch that would go ahead and tell the Ameraindians--which used dugouts--to get back, get back into the side tributaries clear of this coming ore boat or the wave would swamp them--like the tsunami.

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Aplan: --as it went down the Barama River--the lower part of the Burama River ran about two or three miles into Venezuela, so they couldn't use that section without paying an extra duty. So the boat went down the Moro passage and into the Waini--but at the mouth of the Waini was a big mud bar, like a sand bar only mainly mud. Consequently, depending on the phase of the moon, they loaded the ore boat at different tonnages. Sometimes 2,200, sometimes 2,600 depending on how the phase of the moon controlled high tide.

Swent: For the high tide.

Aplan: Wait for a high tide. So if they arrived early, they stayed at the mouth of the river, waited for high tide and then they gave it all eight knots and went over that big pile of mud out there. The ship would actually ride up a couple of feet. You know, on the boats they have these foot marks on the side of the boat? You could see the boat riding up a couple of feet as it went over the Waini Bar. Don't ask me what would happen if it happened to stop in the middle of the Waini Bar. [laughs]

Swent: Oh, my!

Aplan: And then the ore boat went over to Chaguaramas Terminal outside of Port of Spain which had been an old naval station during World War II. Alcan was using it as their bauxite terminal to take bauxite out of Surinam and Guyana, so we were co-using that terminal.

Swent: Alcan was taking it out of Surinam and Carbide was taking it out of--

Aplan: No, I'm not sure, Alcoa out of Surinam but anyway Alcan was taking it out of Guyana. And so we just rented the terminal to trans-ship our ore. We'd bring in ocean freighters load them with manganese ore and take it to Sauda, Norway, or to Newport News or wherever the operations were.

Swent: Where in Norway?

Aplan: Sauda. It's now all controlled by El-Chem which is a Norwegian company.

For plant equipment they originally had to take everything in on a small coastal lighter, load it at Georgetown, and then go up the river all the way up to Port Kaituma.

Port Kaituma's interesting. After Carbide evacuated the property--it turned out later they didn't have much ore reserve so they shut down the whole operation--but the area around Port Kaituma was taken over by a religious sect and called Jonestown. So when I heard about all those suicides down at Jonestown I said I know exactly the place.

Swent: You knew just where they were.

Aplan: I'd been there, yes.

Then there are other ways you could get in. We would often fly a single-engine plane two hours over the jungle and land on the mine road. And that was kind of scary because in a crash, even if you survived, it would take you a month to get out. And then later B.G. Airways put in a twin engine Cessna and they widened out the mine road a little bit--chopped down a few trees and widened the mine road.

Swent: What was the single-engine? Was that a Cessna, also?

Aplan: A Cessna, I think. Maybe a Piper Cub or something like that, because they would carry two or three people including the pilot. But that was some kind of a thrill to do that.

The Grumman Goose was a thrill, too. The only place they could find a wide spot in the river was at a bend in the river and they went along the river bend and chopped down a bunch of trees. Until a Grumman Goose got up on the step, spray came over the windshield and you couldn't see a damn thing! As soon as that aircraft was airborne, they banked because the trees were coming up fast. [laughs] So that was a real thrill.

Swent: Oh my!

Aplan: Well, they had some pretty good pilots--a large number of expats [ex-patriates].

Swent: Well, they must have been good.

Aplan: And they used an Otter afterwards. They wrecked a couple of Geese and so they used the Otter to do that.

Swent: Why did you need to go to these places?

Aplan: We had an English subsidiary called Ore Sales and Services out of London and they ran all of the properties in Ghana, Rhodesia, South Africa, and in Guyana. There was some jealousy and they wouldn't let the American geologists on the property. <u>But</u> I could go because I was in processing, okay? Fortunately I minored in geology.

Swent: Well, you knew your geology.

Aplan: So I often had to do geological stuff kind of surreptitiously. The last time I was there they were getting ready to shut down the property but they had to let it run for another year or two, so they needed to know what the ore reserves would be, how much was in the various stock piles at Chaguaramas and at Port Kaituma, and all that stuff. And they couldn't get a U.S. geologist in to do it, but I could. So I went down there ostensibly to take care of the jig installations, but they had me doing a lot of other things.

I went down there several times, all of it supposedly to help in processing. The last time they had just gotten a new manager down there and I didn't know him too well. The previous one, John Jay, I knew quite well. And I was told to make all these estimates and I started doing it but quickly saw that it was too much, so I finally went to the new manager, Myles Russell. The property manager had a magnificent house and they put up important guests there as well, and I guess I was important; I got to stay in the fancy house. Over a gin and tonic one night I said, "Look, here's my problem. Now, I know what your problem is, too. You've got to keep your English masters happy and you've got to keep the American masters happy, just like me." The two of us made the estimates together. And we arranged that the reports would hit New York and London at the same time. In other words, he would mail it at such a time so it would hit London about the same time I got back to New York. We managed to pull it off.

Swent: What were these reports?

Aplan: Reports on the life expectancy of the property.

Swent: I see.

Aplan: And the grades of manganese that they could expect. In other words, we'd give them several options. If you want it to last this long, you can expect this grade and if you want it to last longer, you expect a little lower grade. We estimated what those grades would be. Incidentally we hit it on the nose. But I couldn't have done as good a job by myself. I had to estimate all those piles and the rest of the stuff and it was a mess.

What prompted the last trip down there was a terribly low-grade boat load of ore which hit Sauda, Norway. As soon as it hit all hell broke loose because it was way off grade. And so they had to know what was going on. And then I got cross-wise of two vice presidents fighting each other in New York. One of them sent me down there to do this and when I came back the other one grabbed me and said, "I want to know what's going on down there," [laughs] so I had to tell him. But I was very uncomfortable being in the middle of a fight--these internecine fights are always bad and you could never win.

Swent: No.

Aplan: So I wasn't about to choose sides. [laughs]

Swent: What was their quarrel about?

Aplan: Who knows, you know! They want to fight in New York, let them fight. I don't care.

Okay, the operation in Guyana was run by about twenty expatriates. Very interesting, a lot of them were out of the British army in Burma, etc. Anyway, they were out of the Far East British army and a lot of them had jobbed East Africa and West Africa. The manager, the assistant manager, and the doctor worked nine months and got three

months back in the UK. They had one relief doctor that went around the various properties and took over when the regular doctor was gone. There would be either the manager or the assistant manager present at all times so the assistant manager acted as manager for the three months the manager was gone. Then the head of the railroad, the mechanical shop, stores, analytical lab, mine engineers, and the mechanical engineer--these guys got one month. They worked eleven months and got one month in the UK. U.S. companies were never that generous with their people overseas, as you well know.

Swent: No. [laughs]

Aplan: The English were always quite generous but these guys--

Swent: They had a longer experience with it.

Aplan: Well, also they were <u>really</u> in the boonies. But they had picked up a lot of make-do ideas. For instance, on Sunday they would invite you over for curry and they would make rice and then they had chicken curry, with maybe twenty-five, thirty side dishes. They would have papaya and cooked papaya, coconut, and toasted coconut, on and on and on with all these things. You'd put it all on the rice and eat that whole mess. Then you'd have to sleep it off for two or three hours, [laughs] so that was Sunday afternoon.

Swent: Sounds wonderful. [laughs]

Aplan: Oh, but I'd never tasted curry like that before! So those people all knew how to do it and they would have these big curry parties and then vie to do a better job than the next person. So it was always just a tremendous thing.

Staff housing was up on the ridge—including the manager's house. They were all up on the ridge so you didn't have to worry too much about mosquitoes because there was always a breeze up there.

The labor crew were either out from Georgetown or they were indigenous and lived in a separate camp.

Swent: Did you have to worry about malaria?

Aplan: At that time--this was before everyone started yelling about DDT. But at that time the British ran Guyana and they had some doctors that cut the salt supply with an atabrine. Since everybody had to have salt, malaria was largely eradicated or controlled. I never worried about malaria the whole time I was there.

Swent: Were you taking atabrine?

Aplan: Well, I was taking some, but also I got it in salt.

Swent: You were getting it in your food, yes.

Aplan: In the salt. Everybody else got it, too--all the native population. So with the exception of some natives way in the boonies--but even they, you know, sooner or later had to get salt someplace--so they had essentially eradicated malaria.

At the camp the Englishmen had made buddies with the arborist in Georgetown who was also an Englishman. He had developed all kinds of plants--but bougainvillea, particularly. He had developed a salmon bougainvillea--I've got a picture of that salmon bougainvillea against a blue sky with fluffy cumulus clouds--just out of this world. You never saw a bougainvillea like that--but there were all kinds of bougainvillea!

Swent: They're so lovely.

Aplan: And then of course there were quite a few macaws there and occasionally they would see a jaguar. But jaguars kept to themselves pretty much; you wouldn't see much of the jaguars. A lot of monkeys, and you would hear those macaws going all the time. And several people had pet macaws.

Swent: What about the water? Did you have to worry?

Aplan: No. Because they had a regular water treatment plant.

Swent: They purified it?

Aplan: Yes.

Swent: Sounds very nice.

Aplan: And they had a good club and you would go over and throw darts and have a pint. It was totally isolated but it was a very compatible, very friendly operation. And of course then as a Yank you got special privileges, I guess freak value or something.

Swent: [laughs]

Aplan: I never heard of a Yank not doing well out there. They always treated them politely.

Swent: A visitor is always very welcome in a place like that. It's a nice change.

Aplan: Well, I wasn't any big shot, I was a peon.

Swent: You must have enjoyed it a lot.

Aplan: I installed a series of jigs down there. That was a real story. We worked out a process to jig some of the ore and recover some additional manganese. I got ahold of Wemco out in Sacramento--they put together a jig--later I saw it and part of it was blue and part of it was brown. They made a brown one for sand and gravel and they made a blue one for iron

ore, so I know they had interrupted a production to do that.

Swent: [laughs]

Aplan: They had put it on a Moore-McCormack boat going down to Georgetown. It went to Georgetown and it was put on a lighter taking it all the way up the Waini and Barama rivers, then put on a narrow gauge, and taken into the camp. And they had it in there a month from the time we placed the order!

Swent: My goodness.

Aplan: You know, we just hit that Moore-McCormack sailing on time. Wemco probably had it on the Moore-McCormack within two days out of Sacramento. But everything just went like clockwork, and it paid for itself in less than a month after installation. So obviously they put in more after that!

Swent: So you were the fair-haired boy.

Aplan: Oh, yes. It kind of tickles you--the president of the Ore Company was a nice guy, but he was an accountant, not an engineer, and I had worked and worked and worked and done a tremendous job on some columbium ore--and I'll get to that in a minute--but they finally were chased out of the Congo, so I got no credit at all for that, but this jig which was a very simple thing worked like a charm and he thought I was wonderful. [laughter]

Swent: Was it a Cleaveland jig?

Aplan: No, this was before the Cleaveland jig. This was called a Remer that Wemco made--it was used mainly for coarse material, whereas the Cleaveland is for fine material.

I also went to Brazil. Carbide had a lot of divisions, and their Linde division made special welding rods. And they needed very low phosphorous manganese ore to produce the slag coating for that welding rod and there was an extremely low phosphorous ore in Brazil in the province of Bahia. And so I went down there and worked on that a while. I'll get back to Rio again later when I--

Research on Columbium/Niobium

Aplan: I spent an awful lot of time on columbium. Columbium is the same thing as niobium. The chemists call it niobium and the metallurgists, mining engineers and mineralogists call it columbium. So we took and made a ferro-columbium for steel manufacture and sold part of it to the chemists to make niobium chemicals out of it. We also had a columbium-tantalum separation plant at Marietta. The input was columbium and the output was niobium. [laughter]

There were four major columbium deposits in the world and I had a chance between Kennecott and Carbide at working on all four of them. The one I've already mentioned is at Oka. For the purpose of record, the formula of pyrochlore is A_2--where A stands for an alkali or alkaline earth element--Cb_2O_5, and then either OH or F--hydroxyl or fluorine--in the lattice. From Oka, the A was in the calcium form; at Araxa, Brazil, it was in the barium form; and in the Congo it was originally strontium that had been weathered out and replaced by hydrogen. So if you knew anything about a lot of these pyrochlores you could tell where it came from. Araxa was eventually run by Wah Chang. I don't know who runs it now, but anyways, Wah Chang in those days.

Carbide had two big deposits. One at Lueshe--in that time it was in the Belgian Congo; now it's Zaire. It's in the extremely eastern part of the Belgian Congo near the Rift Valley--so obviously this columbium mineralization was controlled by the Rift Valley going up Africa. And then there was another deposit north of there called Bingo. But as you know, both at the time of the Belgians leaving and then until Zaire got settled down, our geologist Harry Abendroth was chased out of there several times. He just had to escape over to the Uganda border with his life. The Oka deposit contains less than a half percent Cb_2O_5. The Araxa is at one percent or maybe a little more, while this stuff in the Congo would run 8, 10 percent; 6 percent was low grade and it's still sitting there. The Congo has continued to be in chaos, particularly on the eastern flank, and now Uganda, etc. blow up.

Swent: So it's really inaccessible now.

Aplan: So it's a shame because it's this big, rich deposit and we worked out all the processing techniques and everything. And just as we got them worked out we were kicked out.

Swent: What are they using instead then?

Aplan: Oh, well, this Araxa deposit has just grown and grown and grown. In other words, they have just cranked up the production capacities so a good deal of the world's columbium comes out of Araxa. Some of it out of Oka, but Oka has always been marginal economically.

I was originally sent to Brazil--not for columbium. I should add--let me back up a minute--the principal--[coughing]

Swent: Do you need a glass of water?

Aplan: I'll go out to the fountain. [tape interruption] Historically, the principal minerals for columbium and tantalum was columbite and tantalite--an iron manganese mineral--but then they found large deposits of pyrochlore. But pyrochlore is very unique in that there's almost no tantalum in it. I've seen some pyrochlores in which the ratio of columbium to tantalum is 1,600 to one, whereas often in columbite or tantalite--often one to one or something like that is usually the ratio. Well, there's a mineral called micronite, which is

the tantalum analog of pyrochlore. And carbide's geologists had come up with a deposit of micronite in Minas Gerais near a place called St. John del Rey--I don't know what that is in Portuguese, but anyway St. John del Rey. There seems to be a St. John del Rey in every Spanish country. But anyway, I was sent down there to work on a mill design for the micronite.

Well, I spent about a week in Rio, which wasn't too difficult to take.

Swent: No. [laughs]

Aplan: Working on that design. And then we flew up to Minas Gerais to this property. Well, it was a weathered deposit and it was essentially almost a clay bank with this micronite in it and instead of a mill-- [interruption]

Aplan: I worked on the design of the mill and then I went out to the property. It was essentially micronite crystals in this clay bank. And I told them, "Sluice it. Just get a sluice and throw it through a sluice."

But in the meantime, they were still interested in how they could get some used mill equipment. Governador Valadares--which is also an important city in Minas Gerais--is the source of most of the gemstone pegmatite minerals. So if you get beryl that's gemstone or kunzite it has probably come from Governador Valadares. And there was a mill over there that was for sale.

It had been owned by a company--I think it was called Standard Beryllium--it turned out it was mainly a stock deal. During the fifties beryllium was much in demand and so they built this. Since the mill was for sale and we went out to see this mill.

Well, it was way out in the boonies. And I'm sure you have driven with some people in the third world.

Swent: [laughs]

Aplan: Most of them drive as if they're possessed by the devil. And this guy would drive vigorously down the road with the kids, the pigs, the chickens, the ox-carts--everything getting out of his way. And suddenly he would screech to a halt and then there would be two logs flattened off on top that went across the river and that's how you went across to go across the river.

Swent: Oh!

Aplan: I didn't realize this at first and I made the mistake--I was sitting in the back seat--and I made the mistake of engaging the driver in conversation. But after seeing him drive for a while I decided to be silent. [laughter]

Swent: Leave him alone.

Aplan: Well, we got out in the boonies and here was this mill and it was in a box canyon. And there had obviously been a big pegmatite dike that had been in this area. Probably originally searching for gems--they had started to doghole this thing. And here is the face of this cliff just dogholed with many, many openings. It looked like a Tibetan lamasary, or something, with all these little holes. I expected to see a lama sitting in each one of those holes.

Swent: [laughs]

Aplan: And the mill was something else again. Apparently their engineering staff was a united nations--not United Nations, itself--in other words, from any country they could get an engineer and even some that said they were engineers that weren't. They were going to use shaking tables. They must have gone through Minas Gerais and bought every shaking table in every shape known to mankind.

Some were in new condition; there were those that just had part of a frame, and everything in between. And then someone had told them about a cyclone so they went out and bought cyclones. This mill would probably handle fifty to one hundred tons a day--okay? It was pretty small. They had cyclones all right, but they didn't realize there was a difference between a hydrocyclone and a gas cyclone, so they had these big gas cyclones that were five or six feet in diameter. Now just to give you a frame of reference--a 20-inch-diameter hydrocyclone can handle 2,000 gallons a minute. I don't think there was enough water in that whole area of Minas Gerais to handle those gas cyclones when used as hydrocyclones. But someone had told them to use cyclones so they were installed. Obviously it never ran. [laughter]

Also while I was there I visited the Pacific tin dredge at Diamantina. They were just building a Cleaveland circular jig and putting it on board. [See the ROHO oral history with Norman Cleaveland] It was very interesting to see because they had half the dredge built and so it was like someone had sliced it two. In other words they built the pontoon first then the superstructure. They had built one half and then they turned the dredge around and built the other half. They were building it from the shore, so they were reaching it by turning it around 180 degrees, to build the other half. And so I got to see essentially a cross-section of the dredge.

Swent: It wasn't working? Before it operated?

Aplan: Yes, this was before it was in operation.

##

Aplan: We are still in Brazil and I'm in Rio kind of finishing up writing a report and waiting for the plane.

I should mention that we only had one American in our whole Brazilian operation.

Brazil didn't turn out many mineral engineers. They now do in Minas Gerais, at Belo Horizonte, but in those days they didn't turn out many engineers so we would employ geologists, a lot of them from Rio Grande del Sul. They turned out some superb people. So this subsidiary ran itself with as I said one American in the whole operation. These guys knew how to organize anything. I was really impressed.

Swent: Where had they received their training?

Aplan: I said Rio Grande del Sul--the University of Rio Grande del Sul. And then I think some also from Rio. But as I was waiting for the plane I was having a refreshment with the head of our Brazilian operation whose name was Dick Claus. And his friend was an ex-patriate American who had gone down there as military attache during the war and then married a local girl. He stayed on and he was doing various consulting jobs and so forth. And he said, "Well, now you've been here, what bottled water do you drink?" Now usually if I'm in a foreign country I don't drink any of the water, I drink the local beer. The beer, I've found, is very good and I don't care what country I've been in, I haven't had trouble with Montezuma's revenge [dysentery] from the beer. And so I told him the brand I was drinking and he said, "Well, you know, I was consultant for them." And so he describes to me the bottling works: he went out to the spring and here was a concrete vat with a bunch of little kids sitting on the edge of the vat dangling their feet into the water and they would grab a bottle and dip in there and fill the bottle. The bottles had one of these spring-loaded caps that you used to see on bottles, so that was the bottling works.

Swent: Oh, dear. [laughter]

Aplan: Then he said, I did an economic survey for them and there was a hotel in the Copacabana Beach area, the first street back from Avenue Atlantica, whatever that is, and it catered to the Americans. And at that hotel he did a survey and found that hotel alone sold more of that bottled water than the output of the spring. [laughter] So remember that story as you go to a foreign country and get the bottled water, particularly if it doesn't have a very vigorously stamped-on cap. [laughter] Okay, let's wait until tomorrow and we'll start with tin tomorrow.

Swent: Okay, fine.

Research on Tin and Appropriate Technology in Thailand

[Interview 3: July 22, 1998] ##

Swent: This is continuing the interview on July 22, 1998. And you wanted to talk about tin now.

Aplan: All right. When I was at the University of Washington I did a little work with tin, working with some concentrates from Good News Bay, Alaska, a dredging operation. And of course when I worked at Climax it turned out that we were the largest tin producer in the United States even though we only produced a few hundred pounds a month. [laughs]

When I was at Carbide in the early sixties the exploration geologists had come up with a potential in Thailand and Carbide got an exploration permit to work on this. Now one of the reasons they were interested was not in tin per se, but Carbide had long been in the ferro-columbium/ferro-tantalum business for the steel industry. And it also had then gone into making purified tantalum at the Marietta plant using a solvent extraction process using a ketone and six normal hydrofluoric acid. That was a very tough separation, but it did a good job of separating columbium from tantalum. Tantalum, of course, was in big demand for capacitors and I've already talked about going to Brazil and working on micronite processing. Then Carbide started doing exploration on a deposit they had in Thailand just north of the island of Phuket.

The island of Phuket is off the southwest coast of Thailand very close to the Malaysian border, so it's on that very narrow neck of land going south. I might digress a minute and point out that there's a major tin province running from the islands of Banka and Billiton in Indonesia up through Malaysia, Thailand, Burma, and into mainland China. That's well over a thousand kilometers long and they've found tin along that whole thing. Obviously some changes in the earth's crust put tin there.

Well, just north of the island of Phuket--just off the mainland--they found the massive Thaimaung cassiterite deposit. This was in about fifteen to twenty foot of sediments and about 100 foot of water so this was in the ocean off the west coast. And they had a concession so we brought in a barge to drill that--and we were one of the first to use the Becker drill.

The Becker drill, now, is very popular but at that time the Banka drill was standard for cassiterite exploration. This Becker drill has a hammer that pounds the drill stem down into the sediments and then uses water to lift out cuttings and you screen those out. I was brought in because they wanted a quick evaluation of this. You somehow have to evaluate how much cassiterite you have.

At that time one pound of cassiterite per ton of sediment or ton of ore was considered a very rich placer deposit. And around Kuala Lumpur by redredging they were handling a quarter pound of cassiterite per ton, so this deposit--it will later turn out it was going to be over two pounds per ton--was an extremely valuable deposit but we didn't know that at the time.

And so I was asked to send out one of my assistants--Tim Todd--and he went to work on exploration. Well, we, in our naivete, had decided that we would use a jig, a table, and for the very fine material some heavy liquids. That was fine in theory, but when I got out there and saw the problem, that wasn't the way to go. We ended up--I have a picture in my slides of the chief analyst at Phuket, and it's a woman with a gold pan panning the cassiterite!!

The Thais were superb as were the Malaysians at panning up those concentrates. In

fact, there's a lot of women who would stand at the tail end of the large sluices that were being run on the mainland and pan the tailing from the sluices. The cassiterite, being heavy, tended to stay closer to the sluice rather than flowing out into the pond and the women would stand there all day and pan out these concentrates. Well, tin was selling for three bucks a pound, I guess, and a good wage in Phuket was maybe 25¢ a day, so even with just a little cassiterite they could do extremely well by standing in water all day panning those concentrates. Well, we hired one of those women and she really did the job, so we left all the fancy processing equipment [laughs] sitting and gathering dust while we used a woman to do the panning.

Then I spent most of my time working with the manager and the exploration geologist, Graham Nelson, to evaluate that deposit.

Swent: When was this?

Aplan: In '62, I think.

Swent: I was trying to think what the international situation was--was the tin cartel--

Aplan: Things had just started to pick up in Nam. I knew that because waiting for an airplane at the airport in Bangkok I saw an American plane--a military version of a 707. And they came off that runway so slowly I was trying to pull back to get them airborne. Well, what they were doing was refueling the B-29s. And they were also flying--I guess B-52s.

Swent: Now with the tin cartel controlled--

Aplan: Anglo-Oriental controlled most of it but there was one exception and this was Pacific Tin, but all tin concentrates had to go through certain smelters. And Carbide had another concept. If they found any tin they were going to smelt it and in addition recover columbium and tantalum slags, which they considered valuable feed stock--the cassiterites in Thailand contained a little over 1 percent columbium and tantalum substituted into the SnO_2 lattice.

The property manager was Graham Nelson. And Graham had an interesting history. He had graduated from USC [University of Southern California] as a geologist maybe about 1940 and got a wonderful job in the Philippines. Well, that caused him to spend from December of '41 until fall or late summer of '45 as a guest of the Japanese, in a prison camp. Graham was a tremendous geologist. He had been overseas most of his professional life and the woman he married had been with the U.S. consulate in Costa Rica so the two of them enjoyed being overseas.

We were drilling, as I said, in about 20 foot of sediments and in 100 foot of water using a Becker drill from a barge and then evaluating the material. We had a map showing what the values of the various holes were but we were drilling initially on about 100-meter centers. This was a fairly large deposit. Probably in the widest spot it was

about half a kilometer and at the time I left Carbide, they had delineated at least five kilometers--wow! so it was a big deposit. The cassiterite was very coarse. A lot of that cassiterite was about 10- x 65-mesh, whereas a lot of the stuff they were mining in Malaysia was minus sixty-five going down to 200-mesh, so we had very coarse material, which was easy to recover. And we had a lot of it. We had drill holes that ran ten and twenty pounds and in the evaluation--Well, if I've got a hole of two pounds, and one of twenty pounds; what is it in between? Well, the answer is not nine. The answer is--we knocked everything down to two pounds. And when we finally had the dredge operating, we hit it right on the nose. But Nelson and I had kind of an uneasy time because we had made that estimation and we certainly didn't want to blow that one.

While I was there I ran into an interesting situation. One day Graham grabbed me and said, "Come with me quickly." And we went out by the golf course in Phuket and there offshore--it was probably fifty yards off shore--almost gunwale-to-gunwale were a whole series of boats! Now, what is going on here? Well, apparently there had been a pegmatite dike containing cassiterite that was striking out to sea and over the years this dike had weathered--I might add that the Thaimaung deposits were in situ deposits so the placer tin wasn't transported there. It had been probably in a pegmatite dike, weathered, and then stayed in place, so it was eluvial not an alluvial.

And so in this case, the thing must have been about 100 yards wide and they had put an extension on the motorboat shaft and so the propeller, instead of being eighteen inches from the motor, was now twenty feet. So they would lower the propeller--then they would start the motor as they lowered it and it would churn up the sediments. And the backflow from the waves on the floor of the ocean would carry the sands further out and drop the cassiterite straight down. Then a guy would go down--dive with a coffee can and scoop up the concentrates. He would then come up and they had a 5-gallon biscuit tin wired onto an inner tube and he would dump the concentrates in the inner tube. Then they would take the inner tube on shore and pan up the concentrates. If they were rich, they had a piece of plastic and they dug a little hole along the shoreline and they were panning in that. This was in the days before plastics were readily available everyplace--a thin plastic sheet. If they were poor they would pan it in the surf; otherwise they panned it in this little hole. Then there were all kinds of little shacks selling coffee and goodies for the prospectors so it was almost like an 1849 California gold camp, [laughs] except they went home at night.

But it was really interesting--so as I discuss gravity concentration of fine minerals, I go through the spirals, jigs, tables, and the flowing film concentrators, and I add motor-boat concentration. [laughter] I pass around pictures of the motor-boat concentration and tell them the story.

Swent: Oh, that's wonderful.

Aplan: I also had to work on the design of a dredge. And of course I didn't know anything about cassiterite dredging so I handled that by visitation engineering. There were several

dredging operations in Phuket--at different companies but they all reported to the same master back in London. And then I went down to Malaysia--stopped at Ipoh and then down into the Kuala Lumpur area.

In the Kuala Lumpur area Norman Cleaveland had fixed it up so that we could get on board all the Pacific Tin dredges. And while I was on board one, I got to see Norman Cleaveland's original five-foot, maybe six-foot, circular jig. When our dredge came on line we used big Cleaveland jigs. We probably didn't need to for reasons of recovery--the advantage to the Cleaveland jig is it improved the recoveries of the finest sizes, but we didn't have any finest sizes. There was another advantage, however, of the Cleaveland jig in that it simplified the distribution of ore pulp to the jigs. In conventional jigging they used a line typically of four jigs in a row, each jig forty-two inches square, and they had line after line after line of those things to handle it. Those jigs could handle a little less than a yard an hour--a cubic yard an hour. And of course in any kind of dredging operation you've got a lot of cubic yards an hour and so you need a lot of lines of jigs. Thus there's a real distribution problem of distributing the material and making sure that the last jig gets the same feed as the others. So the circular jig, since there are less of them, really simplified the operation.

As I said, we also had a smelter there called Thaisarco and the smelter was different than the standard smelter. The Thais really wanted to have a smelter. The closest smelter was at Panang in the northern part, so that's on the northeast coast of Malaysia and again controlled by the tin cartel. And there were two problems. Number one, the Thais thought they weren't getting a good price. Whether that's true or not, I don't know, but the other thing is that since the miners had to sell it to the Thai government who in turn sold it to Panang, there was an awful lot of material that surreptitiously went across the border. Okay? And so the Thais, by having their own smelter, could control that.

A Different Smelter with Two Reverberatories and an Electric Furnace

Aplan: So Carbide built a smelter. We built a different one. Usually in a smelter they have typically about three stages of reverberatory--in other words, in the first one they reduce the tin but some of the tin goes into the slag so they put it into another reverberatory furnace and take out a little more tin and then usually they have to go to a tertiary furnace and take out a little more. What we did is we went to two stages of reverberatories and then used an electric furnace. And in the electric furnace we could control the quality of columbium and tantalum that went to the slag. Then that slag was sent to the States to Marietta where we separated pure columbium and tantalum. So this was quite a different process than had been used before.

Swent: What made you decide to do that?

Aplan: Because the ease of recovering the tantalum and columbium--taking the conventional slags wasn't so good. Another advantage is that the Thai slags were richer in columbium and tantalum than were those elsewhere.

Swent: And electricity was readily available?

Aplan: Yes. Yes, but again most of the fuel was fuel oil for the reverbs. The electric furnaces--by the time you got to the tertiary furnace, you weren't dealing with massive amounts of slag so it was a fairly small furnace.

Swent: You said it was called Thaisarco?

Aplan: It stood for Thailand Smelting and Refining Company.

Oh, one other thing, we also did quite a few jig experiments back in the states. Since the deposit was off the coast, we wanted to know how the jigs would respond to wave action and rocking and rolling of the boat and so we had a naval consultant who had worked with our operation in bringing the ore out of Guyana. I think it was Hettinger--Captain Hettinger. But anyway, he had been a German raider sea captain in World War II. [laughs] Yes, he had been to sea all his life so he was well-experienced, and had been out in Southeast Asia quite a while and so he told us what the period of the waves were, what the effect of back reflection from the shore--you know, we were that close to the shore, so what the back reflection was. We were probably a quarter, half a mile from the shore depending where we were in the deposit--sometimes a little more, but you got a back reflection of wave action from shore, so you had to worry about all that stuff.

We were worried that as the seas got a little heavy, and as the boat and jigs tipped, the rush of feed and water coming down would scour out the jig bed and destroy the jig action. So we did a lot of test work on this. We got a small Pan-am placer jig--they were almost non-existent, but Dorr, who finally had the concession from Pan-am, still had a few, so we got one. It was a two one-square-foot cell device and we rigged a big, long, wooden trough and put that jig in line. Then we had a fork lift and knowing what the period was the fork lift raised and lowered that thing. And we were able to cure the problem by having some downcomers just on top of the bed, so if there was a big rush of water it hit these various baffles, to keep them from scouring the bed. So that worked out quite well.

Swent: And where were you doing that? At Tuxedo?

Aplan: At Tuxedo, yes. So that worked out well.

Designing a Dry Plant for Final Concentration

Aplan: And the other thing I had to work on was the design of a dry plant. The concentrate coming off the dredge may contain only maybe 25 percent cassiterite. At least half of the concentrate is ilmenite--of course it's also a heavy black mineral, and of course there's some quartz that gets by--you can't get all the sand out. Our mineralogist identified thirty different mineral species there. Now some of them were in there in vanishingly small quantities, but you had to worry about them.

One you had to worry about the most was pyrite because of sulfur which had to be removed before the concentrate was salable. And of course the other reason is that the smelters didn't want sulfur. And the reason they didn't want sulfur is because sulfur and chlorine, say, from salt, form volatile tin compounds which go up the stack and so you have to have a more elaborate dust recovery system. And once you've got the dusts collected, let's say with an electrostatic precipitator, you've got to get the tin back out. So the name of the game is don't have any sulfur going into the smelter--it makes everybody happy.

Swent: I wanted to ask if it made a difference--I suppose it did--that it was in salt water.

Aplan: Well, you needed to wash the concentrate with fresh water.

Swent: I see.

Aplan: A dry plant, first of all, usually has a wet section to it. And they used a hindered settling classifier called a Willoughby Washer, which was merely a hindering settling classifier that took off the quartz sand that got through the system. Or sometimes they would have a shaking table to take it off.

You then took that concentrate and dried it. It then went to electrostatic separation to separate the minerals which were conductors from those that were nonconductors, and then went to magnetic separation to separate those minerals which were magnetic from those that are nonmagnetic--and so we just weaseled it to the death with this. We finally ended up with cassiterite plus some "cats and dogs," and we used an air table to remove some of the "cats and dogs." To use the air table, you have to size the feed very closely, but it's done. So that's basically the flow sheet. Sometimes we would go back to wet concentration, using a shaking table or something to get some mineral out, but usually that's the general flow sheet. Now, it's a little more complicated than I explained, but that's the rough idea. And so I worked on that design, too, much of it I did in conjunction with Carpco in Jacksonville, who were doing a lot of dry plant work for the titanium producers in Australia--offshore in Australia.

Okay, let's go on.

Swent: It must make it terribly hard to be doing research half-way around the world.

Aplan: No, no, no, what I did--I brought samples back to the States. We had a superb mineralogical group.

Swent: But your plant, your site was in Thailand and here you were doing research and there are a lot of variables.

Aplan: Well, we had a lot of people going back and forth from Thailand to New York all the time, and since the Tuxedo lab was only a little ways from New York City, we had pretty good coordination.

Anyway, let me sum up--a few years later Carbide had a dredge built and started it at the Thaimaung deposit.

Swent: I was going to ask where did you get the dredge?

Aplan: It was built in Singapore in cooperation with IHC Holland, a dredge manufacturer in Holland. And it ran several years, then Carbide got cross-ways of the politics in Thailand or vice versa. Anyway, the marriage disintegrated and without an exploitation concession you're out. You know, like Allende in Chile--you may have a mine today but you don't have tomorrow--you're gone!

So they got cross-ways of that. The Thais also took over the smelter. Apparently the dredge captain got wind of it and he set sail, so they didn't get the dredge. [laughs] And the last I heard, the richest, largest, and coarsest tin deposit in the world is just sitting. We've had several Thai students at Penn State and I've said, "When you go back, try and do something with that Thaimaung deposit because it's a tremendous resource." Now, Thailand still produces tin because they produce it from onshore, in Phuket, and elsewhere in Thailand, but it really was a shame seeing that deposit not being used by anyone, you know?

And then before that happened they insisted that we put in a columbium-tantalum separation plant, so they did. So here's this plant which uses ketones, which are tremendously volatile and explosive--and very strong hydrofluoric acid, and there was a riot where they burned the plant down. Now if I were burning a plant down, one containing ketones and strong hydrofluoric acid wouldn't be it!

Linde Division of Union Carbide and Zeolites

Aplan: The next major project thing I worked on--and I did this over a period of years was zeolites. The Linde division of Union Carbide had produced a series of molecular sieves.

In nature they're called zeolites--but they produced them synthetically. Zeolites are used in ion exchange; they are used to separate a straight chain from a branch chain hydrocarbon in a gaseous form, etcetera, etc. Later they found an awful lot of uses for zeolites. Today they are used in kitty litter since they adsorb ammonia very easily. They're used in cattle feed supplements; they're also used sometimes to add various elements to soil. And those elements slowly bleed out into the soil. There are a lot of trace elements that are needed in agriculture and so you could use zeolites. Anyway, there are all kinds of uses of zeolites.

Swent: But this was new knowledge at that time?

Aplan: Yes and no. The molecular sieve was new and Linde had very strong patents on it, but then they found that there were many zeolite deposits in nature. Now most of us in mineralogy in my era said, Yes, yes, zeolites--you sometimes see a few zeolites in a vug in a lava flow or something. It was a big nothing--you know, there was just no tonnage. But in the late 1950s a Princeton Ph.D. geology candidate by the name of Deffeys discovered in the West--mainly in Nevada--some massive deposits of sedimentary zeolites. These deposits had been formed years ago when there was a lot of volcanic action all along the Sierra. In fact, during the whole Tertiary there was a lot of action. And volcanic ash would fall in a saline lake--like Searles Lake, like Great Salt Lake--and depending on the type of ions in that lake and the concentration--in other words, how much water had evaporated--you formed different kinds of zeolites there.

Successful Exploration for Natural Zeolites

Aplan: So purely on a defensive basis Linde said, Is there competition out there from the natural zeolites? We want to know what it is. So they turned this over to the Carbide geologists. This was the Carbide Nuclear Company and the work was done out of the laboratory Carbide had at Grand Junction. Jim Lake at that time was the manager of that lab. Those in charge of exploration were Bill Koehler and TS Ary so, again, you see these names pop up time after time.

And they had four geologists in the field: Pete Galli, Heywood Wharton, Jim Bright, and Ted Eyde. Ted Eyde had been on loan from the foreign mining subsidiary and some of the time Dick Olson took his place. Those geologists found in the West a fantastic number of zeolite deposits. And they had a very clever exploration technique. Zeolites are usually pale- to buff-colored, so they would go rent an airplane and they would fly all the canyons in the area noting any kind of light colored sediments and then they went in and did the geology on the ground. They found so many zeolites in Idaho, Oregon, Nevada, Wyoming, Arizona, New Mexico, California, etc., that this just swamped the system.

So right away, again, Linde says, Well, how good is this stuff? Okay, so they took some of the biggest and best looking material and started testing them in the lab. Initially, this was tested in the lab by three Linde people: Edith Flanagan, Don Breck, who edited a massive book on zeolites, and Fred Mumpton. Fred Mumpton was a Penn State mineralogist. I later worked with Fred at the Tuxedo laboratory and Niagara Falls laboratories. Fred is now a professor at SUNY, Brockport--State University of New York at Brockport. They started evaluating some of the zeolite properties--you know, how well did they adsorb gases, et cetera. But some samples were not pure so they wanted to know about their beneficiation potential and so I got involved in the beneficiation of some of these zeolites. Later, I'm going to pick up that story when I get to Penn State.

Developing a Superconducting Magnet

Aplan: Another thing I worked on that was very fascinating was a superconducting magnet. It has been found that if you take a niobium/zirconium or niobium/tin compound at about 17 degrees Kelvin--that's 17 degrees absolute--the resistance of the wire dropped to zero.

Now, how do you get down to close to absolute zero? Well, liquid helium boils at 4.2 degrees Kelvin, so if you put that wire in liquid helium it has no resistance. Even highly conducting copper has a finite resistance. Now, if you want to make an electromagnet, the magnetic strength is a function of the amperage you put in and the number of turns of the magnet. Unfortunately, the more turns of copper wire you put in, the more the resistance. Even though it's small, it becomes important. And then if you go to very, very big magnets, you have to put in a massive cooling system. And if you want to put in more amperage--you can't put it in a very thin wire, you have to have a bigger wire, so you get less turns in a bigger space. But if I could design something that had no resistance and so there's no I^2R heating loss--in other words, the amperage times the resistance squared, heating loss--then I could put a lot of turns and put in a lot of amperage in a very small unit. Okay?

Well, Linde was interested because they were in the liquid gas business. Their main business was liquid oxygen. As you fractionate liquid air to get the oxygen you get all kinds of other gases such as argon and helium and Linde used them for heliarc and an argon arc welding of stainless steel. And they said, Okay, what's another use of helium? So they built one of the first superconducting magnets.

I had an opportunity to get a Mark I magnet which was only about twelve inches in diameter. In the center was what we call a hot hole--just a plain hole going down the center--the magnet was in a dewar of liquid helium. This was surrounded by superinsulation which was essentially just a reflective surface. You could use a very bright aluminum or something as a reflective surface and it would reflect heat or keep heat out. Then that was set in a liquid nitrogen dewar. And then there was some more

superinsulation, then a vacuum chamber--as you know, heat doesn't transfer very well through a vacuum--and some more superinsulation. We had about an inch and a quarter hot hole in the center. And that whole assembly was only about twelve inches in diameter and we could get up to 50,000 gauss. In most industrial magnets, 20,000 gauss is a very big deal, as iron saturates at 25,000 so if you're going to use iron, you're not going to go over that--in other words, you can get 15,000--18,000 gauss easily, but as you go between eighteen and twenty-five it's very, very complicated and very difficult, so here we had this wonderful device.

We had to have something non-magnetic so we had a brass tube to put down the hole. We then worked out a splitter device to make ore separations. Many minerals are slightly paramagnetic and so you can separate them. This would be no good for a strongly ferromagnetic material like magnetite or a high-iron ilmenite; of course that would immediately clog up the hole and you wouldn't separate anything. We're talking about things that are just slightly magnetic and there are quite a few minerals like that--monzonite, the rare earth phosphate; rhodochrosite, the pink manganese carbonate--you seem to think that magnetic things have got to be black. Well, this pink rhodochrosite manganese carbonate--anyway, there are a number of things--and even pyrite has a slight magnetism to it. We ran a lot of tests on both wet and dry using this very high strength magnet and got a patent on it, which no one has ever made a dime from, but I have a pretty plaque sitting on my desk. [laughs] And I can say I have a patent on that subject.

Swent: What about the patents--how did Union Carbide handle the business?

Aplan: That was a long drawn-out procedure. You essentially turned the patent over to the corporation.

There was one problem we had--since this magnet was an early model, they hadn't worked out all of the protection methods for the liquid helium and so if anything happened, the helium boiled. And poof!--suddenly the magnet is normal. By normal I mean it has its normal resistance and it could be dangerous because it's essentially a capacitor, so what they did for safety reasons was to plate the eight-mil, [eight thousandths of an inch] Nb-Sn wire with one mil of copper. So the wire, itself, was essentially plated all around and was now about ten mils in diameter. If it was driven normal, then the copper conducted the amperage out of the system, but not before the resistance heat had boiled off all of the helium. So since this was an early version--it would take us almost eight hours; that is all shift to get it running right. And then we would stay there until three in the morning or so and run tests. Once it was critical, you ran as many tests as possible. Some days we went in and had to pack the whole thing in. Of course that made my wife happy because she never knew when I was going to be home or not. [laughs] Sometimes someone would come into the room, slam the door, the helium would splash up, boil, and drive the magnet normal and you had to start all over again hours later.

Swent: Oh!

Learning as a Furnace Tapper During a Strike

Aplan: Then I had another kind of interesting experience. The Oil, Chemical, and Atomic Workers had not been very successful in organizing the chemical industry and so they looked at the various chemical companies and they decided Carbide, which at that time was number two--Dupont was one and Carbide was two in total sales produced--they decided that Carbide was it. But they didn't want to subsidize a lot of strikers for a long period of time so they selected the metals division of Carbide as "it" and they shut down Alloy, West Virginia, and Ashtabula, Ohio, but Carbide elected to keep Marietta, Ohio, running. Now to get it to run, they could take the staffs from there and from their other operations but that still wasn't enough people so they went through the research lab, the sales departments in New York, and so forth and they cleaned the whole thing out and they sent us all down to Marietta to work. We worked seven days a week, twelve hour shifts.

Swent: What sort of work were you doing?

Aplan: I ended up as a tapper on a submerged arc--ferromanganese furnace. You had to wear a big heavy wool coat that came down to your ankles, a helmet, safety goggles, and then there was an eye shield on the helmet, and you had to wear heavy asbestos gloves.

The tapper and the assistant tapper had to get up to the furnace and when it was ready to tap you had to blow a tap hole where there was a weak point in the furnace. This was done with an oxygen lance and then the metal ran out into a fore-hearth. It separated the lighter slag from the heavier metal. The metal, then, was transferred to what we call a chill: it's a cast-iron tray, probably about eight feet square, and they would pour maybe six, eight inches of metal into that. And we had a series of them that could be used. The slag then was pulverized by a water jet--cooled, pulverized, essentially shotted, and was sent over to the silicomanganese operation. The shotted ferromanganese slag, still containing a lot of manganese, was also sent over to a chemical plant where they made electrolytic manganese and electrolytic MnO_2. The electrolytic MnO_2 being used as a battery depolerizer, so Carbide wasn't going to be caught--if the Nsuta deposit ran out they were going to have an option. Actually, the electrolytic MnO_2 was of better quality than the natural ore. So for higher grade batteries they used electrolytic MnO_2. The ferromanganese and silicomanganese alloys then went to the steel industry.

So we had to open the furnace, let the metal run out, and then you had to close up the tap hole. Well, in theory they had a gun and you could shoot a kind of composite of asphalt and carbon to close up the tap hole. The furnace had an outside steel shell with carbon block inside the furnace and carbon electrodes were used to melt the material inside that furnace. So we had to put this matrix of carbon and asphalt in to plug up that hole. It didn't always work. And so we had some kind of conically shaped plugs that could be hammered in the hole of the red hot furnace. To do this, a rod was held against the plug and then someone had to hit that rod with a sledgehammer. And that was my job.

Now, I had been sitting--I was forty-some years old and I'd been sitting in an office for quite a while and [laughs] I had to sling that sledge at shoulder height.

Swent: Oh, my!

Aplan: I would come off shift and we had twelve-hour shifts; I would come off shift, go to my room, take the hottest shower so I could to dissipate all the lactic acid out of all the muscles, then go down and eat a meal, have a couple of good shots of scotch, and go to sleep until the alarm went off. Then I got up and did it all over again.

Swent: Oh, it sounds like very skilled labor, though.

Aplan: Well, no, this was--I was at the bottom of the heap. The crane operator was the regular packing plant superintendent, the chief furnaceman was the plant foreman--or the building foreman--the tapper was the shift boss, and I was the flunkey.

Swent: I see, but still it's something you really had to learn to do.

Aplan: I learned a lot from that. Our staff ran the whole plant and as a result of that we suddenly knew completely what went on in that plant. You know, it's fine to have research, but a lot of times you do research on the wrong thing. As a result of the strikes the quality of research improved massively.

Another thing that happened is we had a whole series of chemical plants on this property and of course they had been built up over fairly modern times--the furnaces had been going since the turn of the century, so the staffing on them was what was needed, but in those chemical plants, we didn't really know the appropriate staffing. At the end of the strike there were 125--I think 128 workers didn't go back because suddenly the management knew how many people it took to run the plant.

But anyway, I think the silver lining on that whole thing--and the strike was finally settled--the silver lining was that the various components of the division knew exactly what the problems were and so the research became much more relevant. And I would imagine the salesmen knew some of the value of the products so I think their pitch probably changed, too.

Swent: You spoke of a fore-hearth?

Aplan: That's just a pot. It was a pot that had a siphon on it because the metal being heavier, settled at the bottom. And we had a siphon and the metal came out from the bottom of the pot and the slag just poured off the top.

Group Manager for Mineral Engineering Research and Development: Identifying Problems

Aplan: The last two years that I was with Carbide--so this would be '66 to '68, or actually December of '67--I was group manager in Niagara Falls for mineral engineering R and D [research and development]. I'd already talked about some of the people I had--I had a really classy group of people working for me, but we spent about a half of our time fixing up plants or parts of plants, mostly unit operations in plants that didn't work. We didn't know anything about these problems until something didn't work and then they called us in. And there were several interesting aspects. Number one, every time we came in they told us what the problem was. Not once was the problem the one they told us had to be solved. People sometimes get too close to something and they can't stand back and say, you know, what really is the problem here. Because we're talking about very good people in the plants, and this wasn't a bunch of incompetents or anything, these were top people, but I guess they were just too close to it.

Swent: Can you give an example?

Aplan: Or maybe didn't know enough about some of the processes. And the other thing is that a lot of the people in the plant and in the design groups had relied too much on vendors. Now, vendors are fantastic sources of information and we have a lot of them in the mineral industry. The fact is, I would say in the mineral industry we've got an outstanding group of vendors. For instance, if you want to put a cyclone in a plant, you get a hold of Krebs and their people will tell you exactly what you need. And we've got a lot of people. The Cyanamid reagent people are the same type of good vendors. But not every vendor in every industry with every piece of equipment is good.

And you get charlatans and you get nice guys that are ignorant and all kinds of combinations so that you can't totally rely on them. In my teaching I have stressed simple design equations and I have stressed to them you can't always trust someone else and here's a simple method that you can use to check out to see if that answer is about right. And that's another example of where my industrial experience helped my teaching because I knew exactly what some of the problems were.

Swent: I was hoping you would give examples. Maybe you know one where the problem was not one of--

Aplan: We had one. It was a metal grinding system. They were grinding up metal to be used as a coating on welding rods and the plant was a real mess. There was too much downtime. Some of the vendors and some of the design people weren't up to snuff. In this plant, the pumps wouldn't pump, the screens wouldn't screen, the drier wouldn't dry, and the sump wouldn't sump--so it was a mess! The dryer--someone had made a mistake and was off by a factor of two. Now, one of the design people said that's okay, because it's guaranteed. Yes, guaranteed all right, and we finally got a new one in operation in four months--who is

it that lost? You know, the dryer we're talking 20,000 bucks or something, but the loss of production was so great that that was only a day or something. So just because you've got a guarantee--and I stress this to the students--just because you've got a guarantee on something doesn't mean--it's like you've got a guarantee on a car and it doesn't work, so you've got to get alternate means of transportation and that's going to be more costly than just a car being down or the fact they put a new little gimmick in it someplace. So I try to teach them just don't trust anyone. Here's some little equations you can use to check it.

All right, let me sum up.

Swent: Well, you had said that in every case the problem was not what they had thought it was. Can you give an example?

Aplan: Ah, politically I'd rather not.

Swent: Okay, all right.

Aplan: By 1967 I had about fifteen years of industrial experience plus teaching experience. I had worked for the largest gold, the largest silver, the largest moly, the largest copper, the largest manganese, the largest chrome, the largest vanadium and uranium, the largest tin producers in the United States. I had worked as exploration back-up on lead and zinc and silver and rare earth and columbium and tantalum and asbestos and barite and zeolite and apatite and magnetite and pegmatites--you name it; I've worked with it! I had done a lot of work with jigs, heavy media, heavy media hydrocyclones, flotation, hydrometallurgy, suspension stability, magnetic separations, and with a number of commodities. And I was able to use most of that when I came to Penn State. So I brought a vast experience to the table when I re-entered the academic profession. Plus some two years of teaching myself, plus serving as a graduate assistant, auditing courses at MIT and seeing how others taught.

In each life some rain must fall. And we had [pause--overcome with emotion] Let me go out and get some water. [tape interruption]

Swent: What year is this?

Aplan: This is going to be January, 1962. We're at 1962. [overcome again; tape interruption]

Swent: It's terribly hard, I know.

Aplan: Our little girl, Margaret Anne, who was nineteen months old, choked to death.

Swent: Where were you living at that time?

Aplan: I was living in Monroe, New York. Shortly before that Doug and Peggy Fuerstenau had lost a daughter to cancer and one of my classmates at MIT, Will Freyberger who went to Michigan Tech and his wife Ruth had lost a son. One AIME meeting we got together and

while talking said, "You know, wasn't it nice when all we had to worry about was going to Brighams in Cambridge and getting an ice cream cone?"

I found the best thing to do was keep busy and so my wife and I did every kind of activity we could think of to do that, but--

Swent: What sorts of things?

Aplan: You don't think about these things for years and suddenly it comes rushing back. [pause]

Swent: I know. What sorts of things were helpful to you?

Aplan: We got into everything you could think of--every kind of activity--dancing classes and square dancing, bridge, and whatever. So when you tumbled into bed you went to sleep. Now, we had two young children that had plenty of needs so that helped my wife a great deal.

Swent: This was your youngest child?

Aplan: This was the youngest child, yes. But as you know, you never forget these things.

Swent: Of course not. Was your religion a help to you?

Aplan: Oh, yes. And though we were six hours from family--my wife had relatives in Springfield, Mass., as well as Boston--that was helpful, too. And we had a lot of friends who were helpful. Bob Woolery's wife Ruth, who was a close friend of Clare, was extremely helpful. And she had young children about the same age, you know.

Swent: That's when you find out who your friends are, isn't it?

Aplan: And then two years later--two and a half years later--we adopted our youngest daughter, Lucy. But when a death happens, boy!

Swent: Yes, that was terrible. Were the Fuerstenaus living near you then?

Aplan: No, no. Doug had gone over to Berkeley. When he left Carbide he went to Kaiser Aluminum and then he was at Berkeley at the time. Give me a few minutes.

##

Aplan: I want to--[tape interruption]

Swent: I suppose that this personal tragedy led to your wanting to leave Monroe--is that part of it?

Aplan: No, no. We didn't leave until '66.

Swent: I see. When did your daughter--when was the death of your child?

Aplan: She died in '62, first of '62.

Swent: I see, so you did stay there for a while after that.

Aplan: Yes, we were there for four more years.

Okay, the Penn State section.

VI PENNSYLVANIA STATE UNIVERSITY, 1967 TO 1998

Heading a Department, Broadening Research

Swent: What did lead to your leaving Union Carbide then?

Aplan: After a decade I got restless and I got thinking, okay, so I'm a group manager, but what I'm doing is supervising other people doing what I've done on the bench, myself, for the previous decade. And I have a kind of a philosophy--if you plot total amount of new things learned versus time, initially you have a very high learning rate and the curve goes up very rapidly and then it flattens and asymptotes out. And in my philosophy, that's time to get out. Unless one has some thinking time, you really don't--you know, if you're in an industrial situation you've got to go, go, go, go every day and you don't have time to think about it, but I somehow made some thinking time.

Swent: And you were doing more management work, I suppose, then.

Aplan: Well, I just didn't feel I was learning much additional material. I'd had a good learning experience up to then, a very high learning rate.

I had thought about teaching and academic research. And with that regard I kind of mentally evaluated the potential for various universities. And I had two criteria. Number one, it had to be a fairly large university so that you have access to good support departments. And two, I didn't want to go to a school where a friend of mine was on the faculty. That might lead to the loss of a friend in situations like that. So I looked down the line and I concluded that the two schools with the best potential--their programs just hadn't been moving and yet they had all these other good things--were the University of Arizona and Penn State. Those were the two.

I had put out the word that I was interested in leaving Carbide. And I was in preliminary discussion with various industrial groups and with universities, when out of the blue I got a call from Dean Charles Hosler here at Penn State. It probably wasn't out

of the blue, actually, because I think Doug Fuerstenau had mentioned my name [laughs] to E.F. Osborne who was the vice president of research at Penn State and had been dean of this college before. But anyway, he said they need a department head. And they had a separate department of mineral preparation and so I came down and interviewed.

The interview impressed me a great deal. Number one, when I got off the plane, the dogwood and rhododendron were in full bloom. And it's just magnificent around here.

Swent: Oh, it must be!

Aplan: The Buffalo area is a little too cold for rhododendron and so they won't grow unless you've got a good sheltered place. Rochester, for example, has a beautiful lilac park. They have a kind of a little valley with a lot of azalea and rhododendron in it, but that's atypical because the gulch is highly sheltered.

So the whole place had attractive plants and out in front of the Nittany Lion Inn was the most gorgeous red rhododendron I'd ever seen in my life!

And I got pretty good vibes. Dean Hosler was a classy individual. He later became vice president of research of the graduate school, still later provost. And the previous dean, E.F. Osborne, who was later the university vice president of research, also interviewed me. I was quite impressed.

Another person who impressed me a great deal in the interviews was Bob Stefanko. Bob Stefanko was head of our mining department. Bob had been injured in a mine accident and spent the rest of his life in a wheelchair. From the wheelchair he earned a doctorate, became department head, was an extremely well-known mining engineer particularly in coal, was president of the Society of Mining Engineers--anyway he was a real producer. When I went in to see him, he started talking about the mine electrical course.

In those days electronics was really coming to the fore and no one in electrical engineering wanted anything to do with electric power--that was just a no-no, you were an old fogey. And so everybody was out of it and the teaching reflected it. And the teacher for that course the students universally reported as lousy, so Stefanko built his own mine electrical course where he talked about electrical machines and DC and AC power transmission and the rest of it. And he would really wax eloquent on this thing, he was so enthusiastic. And I said, Gosh! You know, if he can instill that kind of attitude, we've really got something here! But anyway, I came away quite impressed.

Well, when I got here Hosler told me two things. Number one, he wanted to reinvigorate the operation and number two, he was going to close it down--in other words camouflage it. It was going to be combined with some other unit in the university--and I'll talk about that a little later.

Swent: Okay.

Aplan: So I knew that when I came here. That that was kind of the name of the game.

From my previous experience I had had some very definite ideas--I wanted to stress ores, coal, industrial minerals, and environment aspects. Now, Penn State was very strong already in coal and in the environment but I wanted to get these others. And I wanted to change the curriculum to include particle technology, which would be the characterization of particles, the creation of particles, the separation of particles, and the agglomeration of particles. Well, this is what mineral processors have always done anyway. And when I talk about the Engineering Foundation I'll show you that a group of us in mineral processing have been interested in doing that for years. I wanted to also include such things as applied surface chemistry, mathematical modeling of processes, and chemical processes in solution. And the reason I wanted to do this was I wanted to broaden the job opportunities for students. If there weren't any jobs in coal, maybe he would get one in ore; if there weren't any in coal and ore, maybe he would get one in concrete aggregate; if there weren't any there, maybe he could make use of his applied surface chemistry and go work for some other company. So I wanted as broad as possible program.

If you notice, Doug Fuerstenau was doing the same thing at Berkeley at that time. And those of us doing this talked together, so this wasn't exactly an accident by any means. Anyway, I seized on this as a tremendous opportunity and a very, very good environment. Hosler was a strong supportive dean--

Swent: How old was he?

Aplan: Well, he's maybe a year or two older than I am. So what he had done is he had been a meteorologist in the navy--he had taken meteorology previously--and then after coming out of the navy he got his doctorate and then eventually built the meteorology department here. He's probably the single most important person--we've got the biggest meteorology department in the country here. Probably the best, too. And Hosler really put that on the road. And then he was chosen as dean of the college, and he was a good boss to work for.

And we had also had a very good dean in E.F. Osborne who preceded Hosler. And then the dean that preceded him was Steidle--who went back into the 1920s, though we had short periods in which we had other deans for a year or two, but basically from maybe 1928 to Hosler's promotion to vice president in the early eighties, this college had had three deans and they were all strong deans.

And they had a strong research component--much stronger research component than the College of Engineering. Our college includes the mineral and materials disciplines, so we've got six engineering programs in the college and then we have all flavors of geology, mineral economics, meteorology, and geography--this came from the old School of Mines and they arrived that way because of historical reasons. Geography, for instance, came out of geology. Oh, and material--we've got a big material science

department: metallurgy, ceramics, fuel, and polymer.

Swent: And this was all in the school of minerals--the college of minerals?

Aplan: Earth and Mineral Science, yes.

Swent: And then there were the other engineering: mechanical, and EE--

Aplan: That's in another college.

Swent: I see.

Aplan: So we actually had some liberal arts disciplines, some science disciplines, and some engineering disciplines. It's quite a unique set-up, but it's been a very effective, productive college.

Swent: That's still kept as a separate college?

Aplan: Yes.

Swent: What was the student population at that time?

Aplan: Well, the student population has been reasonably stable for twenty-five years with the exception of that big blip during the energy crisis where the mining and petroleum engineering enrollments went out of this world. Right now the department I'm in--they're just in the process of changing the name, but it was called mineral engineering--includes mining engineering, petroleum engineering, mineral process engineering, geo-environmental engineering, mineral engineering management--

Swent: That's five.

Aplan: Oh, gosh. Yes. And there was a big blip for a few years, but now that that's settled back down, I would guess we probably have 600 graduate students and maybe 1200 undergraduates in the college.

Swent: That's a lot.

Aplan: So basically it is about the size of Montana Tech, Colorado School of Mines, and South Dakota School of Mines in total for those schools.

There is another strength to it and that is the library. We have a separate branch library--always have had. We have vigorously resisted any amalgamation which has been a good thing. And I do a lot of work in mining history and so I said, Why do we have these good collections of *Mining and Scientific Press* and *Engineering and Mining Journal*, et cetera, going back into the last century? Well, there were two reasons for that.

Apparently in the early days when they were in a bunch of wooden shack buildings the professors used to keep various journals in their office and so when the building next to us was built--I think in 1928--all those collections came together to form the library and all those professors disgorged all the stuff they had to the library.

Another thing that happened is there was a professor by the name of W.R. Crane who wrote a book called *Index to Mining Engineering Literature*. It was two volumes: 1909 and 1912. Now, mining was used in a broad sense, so if you want to know anything about mining at the turn of the century, he's got a complete literature for mining, extractive metallurgy, and geology.

Swent: And he did that here?

Aplan: He did that here. And it's a tremendous work.

Recruiting a Faculty from Around the World

Aplan: After I came here, six months later, Len Austin joined us. Len had been a faculty member here in Fuel Science and then went down to the Chem Engineering department at N.C. State. Well, he decided he wanted to come back to State College and I had known Len from the Engineering Foundation particulate matter conferences and so when he walked in my office it was like, welcome, said the spider to the fly; I was happy to be able to get him. [laughter] He is a very good expert in comminution--crushing and grinding and in mathematical modeling and we were like-minded about particle technology and these other things that I've mentioned that had been discussed rather broadly among a half dozen of us.

And a year later, Dick Hogg, who was a graduate student of Doug Fuerstenau's at Berkeley, came in. And he did particle technology and surface chemistry. And then several years later Osseo Asare--also one of Doug's students--joined us and took over the hydrometallurgy course. I was teaching hydrometallurgy and when he came I said, Happy to see you here! And then a few years later, Subash Chander, another one of Doug's grad students, joined us and he does applied surface chemistry and flotation.

A few years later we picked up one of our graduates--Pete Luckie. He had been director of research for Kennedy Van Saun Corporation in Pennsylvania. And he handles process evaluation--gravity concentration and economic factors. Pete is now Associate Dean for Research at the college, but he still does a little teaching and some research. And then we've had two more recent additions: Mark Klima, one of our own doctorates--he handles coal preparation and gravity and economics and process evaluation. Essentially he took over from Luckie.

And then the most recent addition is Thaddeus Ityokumbal. He's a chem engineer originally educated in Nigeria and then he did his graduate work at the University of Western Ontario and worked for Canmet for a while before coming here.

As I've mentioned, when I got here the department strengths included coal prep. For many years--dating from the twenties--Dave Mitchell did coal prep. Dave Mitchell was the first author of the coal preparation volume published by AIME/SME and it's now in a fifth edition. It's the biggest seller that SME has ever had and he did the first four editions. On the third edition he was helped by one of our graduate students--former graduates--Joe Leonard, who is now a professor down at Kentucky. And then Leonard has taken over and been the editor of the last two editions.

And then I should mention Dr. S.C. Sun--Sun had his doctorate with Gaudin at MIT and came here about the end of the war. And he was doing quite a bit of work in coal flotation. In 1954 he had two really classic papers. If you do anything in coal flotation, you're going to cite one of those two papers.

On the environmental front they had started early, but the real catalyst was Beecher Charmbury. He had come out of Fuel Science and had taken over as department head in probably '49--something like that. And he immediately started going after some of the environmental problems. Now, Pennsylvania had a lot. There was essentially a billion tons of anthracite refuse above ground in eastern Pennsylvania dating back probably into the late 1600s. And you know, the reality was that anthracite was sold too cheaply. They should have charged an extra dollar and put it in an environmental fund so that the people in New York and New Jersey and Massachusetts and so forth--we got their environmental problems and they got the anthracite to burn.

But Charmbury looked around and saw there was a lot of problems. We had a lot of streams polluted with acid mine drainage and he started working on these--particularly on acid mine drainage and in reducing the coal mine refuse and trying to recover some coal out of it because another little problem they had is that if they didn't get all the coal out of the refuse the pile would catch fire; then the rain would come and leach some of the pyrite and give you acid mine drainage. They didn't need a fire to do that, but with the fire you ended up with a lot of pollution. As a matter of fact, when I came here there was a big coal bank on fire at Wilkes-Barre. And this wasn't uncommon. Well, Beecher saw this and started really working on that problem. He didn't have too much money but he was fairly successful in getting various monies and he got money for a couple of fairly large pilot plants. And the school was actually running bituminous and anthracite refuse recovery plants--in other words recovering good coal from the former refuse.

Swent: This was in the late sixties?

Aplan: No, this in the fifties and early sixties.

Swent: So very early.

Aplan: In 1963 Charmbury was appointed State Secretary of Mines. The secretary, like the others, was in charge of all the mining activities of the state that impacted the state government. And he started a big campaign of environmental remediation--but he had a lot of help. Governor Scranton appointed him and was also a big help. And the state voted a $600-million bond issue. Now in the early sixties, $600 million was a neat piece of change. And it was specifically for environmental remediation. In addition, they took that money and leveraged it with government money.

Swent: Federal?

Aplan: Yes, out of Bureau of Mines and out of what is now the DOE. There was no DOE at that time, but out of all those various groups--the Ohio River Sanitary Committee, and on and on and on. And the purpose of that was to work particularly on the acid mine drainage and on the refuse problem.

He took with him down to Harrisburg as his assistant directors Chuck Manula out of the mining department, who handled the mining end, and Dave Maneval from mineral preparation. Both of those were young assistant profs in the college and since Maneval was director of research, they really put the show on the road. They had a good support staff that really knew what they were doing. Then they left behind in the department Harold Lovell and he did the in-house department research, mainly in acid mine drainage. And later they built a big pilot plant which he manned.

Swent: Were you able to integrate that with your students' programs?

Aplan: Well, I wasn't here then. This was before I arrived. I wanted to establish that going back into the fifties and sixties Penn State had really thought about environmental problems and was really doing something about it. They put out underground fires, they did a lot of stuff with the Bureau of Mines and all these other organizations, they capped abandoned oil wells--we had a lot of old oil wells going back to before the turn of the century in the northwest part of the state. One of the outstanding projects is Moraine State Park. That had acid mine drainage from old mines, uncapped oil fields and refuse coal banks all over the place. It's a state park today--beautiful.

Swent: Well!

Aplan: So they really did a job. Charmbury did such a good job that he was the first winner of the Queneau medal of the Audubon Society. And if you ever heard any mining person that ever got anything from the Audubon Society--

Swent: Not often! [laughter]

Aplan: Well, he did. He did. So I wanted to broaden into those other opportunities, as well. I certainly didn't want to leave that environmental work behind. And I'll point out we

haven't.

But I looked at this whole thing as a real opportunity. And of course I had a head full of ideas that I wanted to put into practice in both teaching and research. In teaching, we put together--and this was mainly Austin, Hogg, and myself--so after about the first year we really started moving--we put together courses in particle technology. There are about half dozen courses in particle technology now. We put together courses in applied surface chemistry, we put together a course in mathematical modeling, we expanded the hydrometallurgy offerings, and then when Osseo came in, we really expanded it. Osseo won the Douglas gold medal of the AIME for was his work in hydro, and Austin and Hogg are Gaudin awardees. So you know, we're dealing with quality. We expanded flotation and we expanded environmental--and I'll talk about that later.

Environmental Pollution Control a New Concern

Aplan: In the environmental courses in about 1972--it may have been '71--anyway, early seventies--I developed a course called Pollution Control in Mineral Process Industries. We were a part of the metallurgy program at the time and then I carried that course when we came over and became associated with mining. I developed the course, organized the course, and taught the course--because our philosophy was that mineral processing and hydrometallurgy are subjects you'll use in most environmental remediation anyway. The same phenomena in acid mine drainage and in waste streams containing metal ions--that's hydrometallurgy. If you're going to do anything on land remediation, you're going to use mineral processing one way or another.

So I put together this separate course--and because we had these courses in particle technology and surface characterization that are important if you're going to do anything about air pollution; you've got to characterize the particle first before you can design a removal method. And I was very interested in pointing out to all the students as I taught that course that number one, the first electrostatic precipitator which is now used on every coal-fired power plant, was at a lead smelter in Selby, California, about 1915; the second one was at Anaconda Copper Smelter about '16 or '17; and the third one was at a lead-zinc smelter in Midvale, Utah. And I make sure they know about that. [laughter]

And I also make sure that they know about what industry used the bag house, first for recovery of fine particles, i.e. the nonferrous smelting industry. Now, they weren't using it all for environmental reasons. The main reason they wanted to recover the dusts from lead and zinc smelting is because they contained cadmium and indium and galium and so forth that were very valuable and were the principal source of those elements. But I made sure that they knew that these things were being done early on by this industry.

Swent: Good historical sense never hurt.

Aplan: Oh, yes. And then as our nation started doing a lot of clean-up on old smelters, I made sure that our students know that when you hear all this yelling about the smelting industry, two things have happened: number one, we've shut down half the smelters--half the lead, zinc, and copper smelters--so roughly their sulfur emissions were halved and secondly we've improved the SO_2 capture from about 19 percent in '65 to today where it's well over 95 percent SO_2 capture from copper smelting. So the pollution is not coming from that industry. And I point out the same thing in coke ovens--what's been done in coke ovens. I've pointed out the same thing in power plants--where power plants in a ten-year period--in the eighties we doubled the coal use and halved the SO_2--mainly by fuel switching, going to lower sulfur sources. But anyway, we've done a tremendous job of sulfur reduction.

Swent: Right.

Aplan: Then, we developed, at about the same time, an interdisciplinary masters degree program in Environmental Pollution Control--mainly Engineering, EMS and Ag [agricultural] colleges--but to a lesser extent the College of Science. And I started out as our college's representative to that committee. A student could get that environmental pollution control degree by taking some core courses and then taking additional courses in sanitary engineering, mineral processing, metallurgy, mining, agricultural engineering or whatever. We had an approved list of courses and an approved list of departments from which the students could select.

Swent: Has this been popular?

Aplan: It was for a period, but it has sort of died out. And I'll show you the reasons why it died out in this college. It's still fairly common in the College of Engineering and to a lesser extent in ag. But ag put in a different environmental program which siphoned off students and EMS also put in one.

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Aplan: Professor R. B. Ramani introduced an environmental course in mining as a team-taught course. Professors Mutmansky and Phelps and myself together with Ramani team-teach this course. I handle the mineral processing side and each handled his own--Phelps will handle the surface mining component, and so each will handle a different component.

In Mineral Engineering two other programs have been initiated. One is a course in Geo-environmental Engineering which came out of mineral processing. And out of mining came a program in Industrial Health and Safety. The mining departments have always been strong in modern times in mine atmosphere control, i.e. suppression of mine dust. Silicosis was historically important as was black lung [disease], so they've done a lot of research in the department on that. Anyway, and as I mentioned before--pollution control, again--mineral processing and hydrometallurgy--if you know those things you've

really got a leg up on this kind of remediation. And in my "Elements in Mineral Processing" I show that mineral processing has a big impact on pollution control. I've already mentioned the electrostatic precipitator and the bag house which came out of the metallurgical industry.

Early, oh, probably about 1992--this was about the time I retired formally--there was an idea generated in the mineral processing faculty for a geo-environmental engineering degree. For this one we had Dean Cahir, who was the Associate Dean for Academic Affairs, behind it and of this came the concept of having a subset in land, air, or water pollution control. So in water we would make use of hydrometallurgy and our groundwater people in geology, and for air we could make use of our strong meteo department. In solid waste we had the mineral processing. There is a core group of courses and then students can also specialize in one of these subsets. The first student graduated only three years ago and there are 170 students in the program now.

Swent: Whew! That's where jobs are.

Aplan: Well, quite a few, plus there's a lot of PR [public relations] there, too. Now, the principal person in this program was Professor Richard Hogg, a mineral processing prof. He took the leadership both conceptually and administratively for this. And you can imagine with that many students it's a lot of work.

Swent: It's a lot.

Aplan: He's done a yeoman job on doing that.

Teaching Elements of Mineral Processing, 1968 to 1998

Aplan: I arrived at Penn State January 1, 1968. In the fall of 1968 I started teaching the "Elements of Mineral Processing" course, the introductory course typically given to juniors. And in addition so far, I've taught five years past retirement. We were short on faculty and I was happy to help out and teach that course.

In that course I stressed problem-solving discipline. We have a complication at Penn State--at a school like South Dakota School of Mines or Montana Tech or Colorado School of Mines, etc., all the students are technical students and they all go through a standard course in engineering mechanics or so forth so they can be taught a problem discipline: now here's how you set up a problem, here's the type of paper you use, here's how you underline your answer or box your answer, etc., etc., etc. I was getting turkey scratches all over the paper and it was just chaos to correct. And the reason is that the bulk of the freshman and sophomores at Penn State are at nineteen branch campuses scattered all over the state. There are close to 70,000 students at Penn State, 42,000 of

which are at this campus; the rest are scattered all over. And so those branch campuses operate as a two-year feeder into the main campus. They also have a few four-year degrees out there but for courses like this they go two years to one of those branch campuses and then come up here. It's a lot cheaper that way; they can initially live closer to home.

Swent: They don't call them community colleges, though? They call them Penn State?

Aplan: The community college system did not develop very strongly in Pennsylvania. And the reason was Penn State essentially already had one.

Swent: You already had one. They call them branch colleges.

Aplan: Branch campuses. They're in the process of reorganizing and changing and some of them will grow into four-year colleges. Right now three of them have graduate programs. One has a complete four-year--completely detached, except for the name--for history, English, social science, etc. Much of the technology still comes to this campus, although we have technology programs at our Harrisburg campus. Anyway--

Swent: So you were getting juniors from all these branches.

Aplan: From all over. And I would get turkey scratches all over the paper because none of them had the same background. None of them had the same teachers. Okay? And this college typically got most of our students by transfer from these branch campuses.

Swent: Were you also getting a lot of out-of-state or out of the country--foreign students?

Aplan: We get a lot of foreign students in graduate programs, but for undergraduate essentially the only out-of-state students--the tuition at Penn State is among the highest of the land-grant colleges in the United States. I think Michigan and New Hampshire and Vermont also have very high tuitions and so the out-of-state tuition is very high. But our out-of-state students are usually legacy students. The admissions office will put toward the top of the list children of alums. Now of course if you are a football player or a basketball player or a lacrosse player--if you see a lacrosse player, he probably came from Long Island. [laughter] The high schools on Long Island are likely to have big, strong lacrosse programs--and we have a strong lacrosse program here.

Stressing Problem Discipline

Aplan: But I stress problem discipline: doing it in a formalized manner. I had one problem set a week, so in a fifteen-week term they get about twelve problem sets and each problem set would have about four--between three and five subsets. These would include mass

balances, slurry flow, costs, comminution crushing and grinding--and in the course I've always stressed comminution. That's not my major field, but 60 percent of the costs, say, in a copper plant are crushing and grinding. Stoke's Law--a means of talking about the settling of very fine particles, typically particles less than a tenth of a millimeter--100 micrometers--fall in that range. And there's a settling law called Stoke's Law and it works fantastically well. It's rarely off by more than a factor or two--usually just 15 percent off or something like that. And many engineering calculations are not that tight--or we build a safety factor in to take care of it. And so this is very helpful in air and water pollution control and all of those aspects get incorporated into that course, and I have problem sets dealing with those various areas. Okay.

Swent: Were these theoretical problems, or were they doing laboratory work?

Aplan: No, there's a separate lab for this particular course. With the exception of a couple of problems to begin which are synthetic problems, all the rest are based on practical data. And every year was a new problem. I had to make up a new problem set every year. Now, a lot of times I just changed the numbers, but they just couldn't go and crib the set. I put into the library a previous year's problem so they knew exactly what I was after. They saw how other people handled a similar type problem--not the same problem but a similar problem--because I've always thought it unfair that various fraternities or other living groups had big files while these single students scattered all over with no friends had nothing. And so I said, "Okay, I'll fix that." And I put these old problem sets in the library. I made available several copies, because even though they had one week, you realize some students waited until the night before [laughter] the problems were to be due so I would have maybe three or four copies of the problem sets available.

As I mentioned before, I stressed simple design equations. I was probably rated as a tough task-master, but I have had the pleasure of having a lot of former students come up to me at an SME meeting and say "Thank you." And the classic was one time I had--within a period of about a month I had two different sets of parents come and see me and thank me.

Swent: Well!

Aplan: Well, the students have done outstandingly well after getting out of here, so I take a great deal of pride in that. And of course that's one of those experiences where you walk about three feet off the ground.

Swent: That's right. That's the gratification of teaching, isn't it?

Aplan: Mind you, I wasn't quite good enough to walk on water, but--[laughter]

In teaching that course, for each section that we talked about—such as concentration, I would have a little section on why are we doing this. I would tell them about how can we use it and where it fits into the whole fabric and what the alternatives

are. So for instance, as we talked about sizing I would show them the different types of screens, what particle sizes they could treat, what size various other devices such as a Stoke's Law type of device can do. When I got to concentration equipment I told them where hand picking, and where various devices would work, starting from six inches and going down to micrometer- size particles. I wanted them to see the problem as a whole.

I developed a simple handbook. It took me thirty years to develop, but I put all this supporting material down on paper. It didn't duplicate the lecture; it augmented the lecture. And then I would show pictures of industrial operations, pointing out various aspects. When I wanted to show them the effect of increasing the size of a flotation cell, I showed them a picture of the original Butte concentrator which had 100-cubic-foot cells and I showed them then Pinto Valley, which used 300-cubic-foot cells and I showed them that both plants had the same capacity but Pinto Valley used half the floor space. And now we're using over 1000-cubic-foot cells and they can easily see why we go to the big cells--it cuts down the floor space and if you have to build a bigger building around it, it's a much smaller building.

Swent: That's right.

Aplan: So I would show them that equipment and then I would show them the historical predecessors. I would start, for example, with an old Spanish *arastra*. I have a picture of a beautiful one from Buckskin Joe, Colorado, outside of Fairplay. And then I would go to a chili mill and then I would go to a roller race mill which is used for pulverized coal firing of a boiler. And they could see the development of the device through the centuries and I would do that for a lot of equipment.

When I got to jigging I went back to the story of the Greeks jogging a basket of ore up and down in the water and noticing that the lights came to the top and the heavies went to the bottom. They originally had started that to wash the ore so they could hand-pick it more easily, not to concentrate the ore per se. So anyway I go into all of that stuff to show them what the predecessor was.

Teaching Flotation in a Unique Hands-on Laboratory

Aplan: I also did a lot of teaching of the flotation courses. We have both a graduate and an undergraduate course. I tried to summarize the various topics into different units and stress the important things. There was a lab with both the undergraduate and graduate course. I think in the graduate course I probably had the only hands-on graduate laboratory course in the country.

Swent: Really?

Aplan: Most people treat that as a theoretical approach. I, over the years, gathered up about thirty different ores that I would use to teach--I would give them tough ones, not easy ones. A complicated lead-zinc ore--usually lead-zinc ore separation is duck soup, but I had a complicated one. We went into the flotation kinetics of copper ores. Then we went into the emulsion flotation process and I showed them the flotation of molybdenite and coal and manganese dioxide and the agglomerate tabling of mica and show them that is all the same process. And then of course the references and the report had to reflect the literature. We looked at various ways to float base metal oxides--minerals like malachite and azurite, smithsonite, etc. We did a separation of pegmatite minerals. To get their feet wet we made an artificial mixture, say, of mica, feldspar, quartz, beryl, etc., and then we separated them out and looked at them under the microscope. And then I gave them some actual ores from the pegmatites in North Carolina and had them separate those. Then we looked at design techniques, etc. Anyway, I was quite proud of that lab.

Swent: You must have been a wonderful teacher.

Aplan: I don't know whether I was a wonderful teacher or not, but I covered a lot of material. And the thing about these different ore samples: a lot of those mines no longer exist. A lot of those mines are shut down and so forth, so I had all these ores from hither and yon, all illustrating various principles.

Over the years I've taught a lot of courses in hydrometallurgy and particle tech, but as soon as a new faculty member arrived, I gave it to him.

I guess one of the pet peeves I have is all too often in courses--I'm not talking just mineral processing, but courses in general--in graduate courses professors love to come into class and spend their time discussing their own research in depth. And you come out of it saying I learned rather more of that subject than I really wanted to know. I tried principles. For example, in my elementary course, even though my principal research effort was on coal flotation, I would cover that in three to five minutes. That was all. In the flotation course--undergraduate--I would spend about one lecture on coal flotation or less. I didn't want to go into the intimate details. They can always look it up in the literature, but I wanted to stress certain principles--and again, having worked in all kinds of different industries, I stressed various aspects.

Let's start the research. I don't think we can finish it, but let's start.

Swent: Okay.

Aplan: In research--and as I pointed out, this college historically is heavily oriented toward research—though not to the exclusion of teaching. For example, if you do all research and do lousy teaching you won't be tenured. You have to do a fairly good job of teaching. If you do absolutely outstanding teaching and lousy research you may have a tough time, but if you do wonderful research and not so good teaching you're going to be in trouble--they'll hassle you or you won't get tenured. So the college has always valued teaching as

well as research.

Swent: It's very important.

Developing Self-Reliant Graduate Students

Aplan: But the fact is, the research wags the dog. Maybe others won't agree with me, but that's my own bias. Graduate students come from various sources both U.S. and foreign. Many graduate programs in minerals in the United States are largely foreign. I've had about a 70/30: about 70 percent from U.S. and 30 percent foreign. Most of our grad students--and mine are typical--are re-treads and I would say many did not come out of mining, metallurgy, or mineral processing. We've had them out of chemistry, biochemistry, geology, civil, mineral processing, mining, metallurgical, civil, mechanical, chemical engineering--so any technical person. And the make-up courses for our program are fairly simple and straightforward. They have to sit in on an elementary mineral processing course for example. You don't even have to take it for credit, though we figured the mechanism to give one credit for doing that.

With grad students my modus operandi was to try to develop some self-reliance. A company doesn't want someone to come out and pester the boss all the time with, "What am I now supposed to do?"

Swent: No.

Aplan: So I tried to develop that independence. And so when new students came in I would spell out the problem I wanted them to work on. I'd give them some idea of the literature in the library, or may give them a previous thesis, or go have a student who is still here or who was working on a similar project tell him about it--somehow give him copies of old theses on the same subject or similar topics and leave them alone for about a term. At the end of that time, I went in to see if they were producing or not. Oh, I would stop in and check to see how they were doing, but it was mainly social during that period. I would ask if they had any major problems or anything, but basically I would leave them alone.

The rest of the time I probably pester them to death--pop into the lab every day or more than once a day and find out how it's going on.

Swent: [laughs]

Aplan: So if after the term they weren't producing, I would then step in and I would give them hand-written things to do, etc. At the end of the year if they weren't producing, one way or another, they were gone. Most of them were smart enough to realize that that wasn't their bag and they should go elsewhere.

Swent: Did you have a master's program?

Aplan: Oh, yes, a strong master--and I'll point this out. I have produced more master's degree people than Ph.D.s and I'll point out why. I have been very proud of my students and I'll talk just a little about this. In 1984 I had leukemia and I was in the hospital a total of over three months over about a ten-month period. I did six months of out-patient chemotherapy and I was sick all the time. And then I had to learn to walk again--and I'll talk about that a little later--so I wasn't much help. And I had seven grad students at the time. Six of them worked and when they came to a fork in the road, did all the right things as if I had been here. In other words, if they had asked me, that's would I would have told them to do. For the first two months after getting leukemia, I was totally out of it. I was totally isolated in a room by myself, period. I had no immune system so they had to keep me away from everyone. Six of the seven worked and did everything right. There was one loafer, and the one loafer suddenly saw he had six months extra work to make up and left. It's a shame, he was a damn smart kid, but he just wasn't motivated. But I am really proud of my students. As a matter of fact, out of my nearly fifty grad students, I can say about each and every one of them that got a degree, "That's a good man," including three women--so I use the word man, i.e. mankind. The women, I might add, today all have doctorates. Two of them got doctorates with me and another one went out and worked and got a doctorate while working full-time--motivated!

My students were all hard workers, they're all self-starters, they're all problem-solvers, and they're all well-educated. I did have one problem child. And if you had asked me three years ago, I would say I've got one exception, but he's gone out in industry and he's really taking off. So I am just pleased as punch about my students. And if you want to ask me about each and any one of those students I've had--now they all have different strengths and weaknesses, but I can talk positive things about each and every one of them and I can mention those fine features--and I'm very pleased about it. These excellent students were: P.K. Ackerman, B.J. Arnold, S.B. Balachandran, C.M. Bonner, P.B. Bradley, R.M. Carland, M. Castillo, Y.H. Chen, V. Choudhry, R.S. Datta, E.C. Dowling, M.J. Engler, M.C. Esposito-Brick, J.A. Gutierrez, W.C. Hirt, C.J. Im, T.J. Laros, M. Lizarazu, V.E. Lundberg, K.D.Mondale, D.A. Moro, T.J. Olson, T. Onlin, B.K. Parekh, J.W. Perez, R.W. Perry, R.J. Purcell, C.E. Raleigh, R.L. Ranich, S.Ranjan, R. Rastogi, R. Rey, V.D. Smar, E.Y. Spearin, K.C. Thompson, R.S. Thompson, R.L. Waterman, D.D. Xu, J.M. Zarachansky, and C.E. Zebula.

Swent: That's wonderful.

Aplan: Another problem you sometimes run into is with foreign students. Some foreign students come from a two-class society where they have never gotten their hands dirty. I work on practical problems, largely, or fairly sophisticated laboratory things and they either learn to use their hands or they depart. I've been very fortunate. A couple of the students had, even though they were foreign students from the third world, had had industrial experience so they came in and they were ready to go. But if they don't, you understand

that. Having traveled abroad, I understand the two-class society and some people, through no fault of their own, really don't know how to shovel, don't know how to use their hands, don't know how to use a pair of pliers, etc. And you have to step in and do something about that.

The main emphasis of my research has been to have an industrial component--not every time, but mostly. I want to tackle a real problem. You develop a hypothesis and a theory and then you need data. Now, I learned something when I was at MIT from the great white man [Gaudin] and he was around all the time, and the great white man of chem engineering was W.K. Lewis. He was pretty well known as the father of modern chem engineering in the United States. And W.K. Lewis had a statement: "If the data don't fit your hypothesis, consider that your hypothesis is wrong." Too many people get some theory and they ride that to the bitter end. And it usually--

Swent: Or fudge the data.

Aplan: Yes, and usually the demands of a mineral engineer are such that they don't have time to follow that thing to the ultimate end because the industry is too short of people and the demands on the people are very high. You know, you can go to a 50,000-ton mill and maybe four technical people can run that whole operation--and the superintendent and the assistant superintendent spend an inordinate amount of time on labor relations, which means they can't be spending it on technical. I also began to insist that all of my students have a good knowledge of engineering economics--not only what is in the book by Don Gentry and Tim O'Neil, but also some formal course work, typically a course we teach in the department.

Visiting Mining Operations and Attending Conferences to Keep Current

Aplan: In order to keep myself current I visit mining operations. At AIME meetings or any other meeting--I'll take that opportunity to visit the plant operations. I have all of the Mill Operators Conferences from Australia. They do a superb job on that--and all of the Australian Coal Preparation Conferences whose members range from foreman through the academics, so you get everything there. We have no analog to that in the United States. We have different conferences to handle different things. However, I have all of the SME applied conference proceedings and all of the Randall Gold Symposium proceedings, etc. And my personal library is massive.

Swent: Have you attended most of these conferences, as well?

Aplan: Since I was at Union Carbide I've attended the bulk. I guess, with the exception of two times out for cancer, I've attended every meeting of SME since the early sixties.

Swent: I was wondering about the Australian ones. Have you been there?

Aplan: I've been out to Australia four times. That's where I heard about these things and I was so impressed that I used to write to Australia to find out what's going on, but now I've got enough spies that will usually keep me informed. Also in the last three SME meetings, Aus-IMM has shown up and had a booth at the equipment show. So I go to that booth and say, "What new books have you come out with?" And then I order them. And the books are reasonably priced, but the postage--[laughter]--is high and the sea post is useless. I think they lash it on the back of a turtle and throw the turtle into the Pacific, hoping it comes this way.

I have already tabulated a list of my grad students but as I discuss individual research projects, I can't possibly mention all the names. I'm going to mention a few and those that are left out, I don't want them to feel cheated because it just happened to come to my mind at the time.

But most of my research is based on coal flotation, processing of industrial materials, environmental aspects, gravity concentration, ore flotation, and a kind of catch-all I will call "general". I'll talk about each of these separately. Let's go.

Swent: Do you think that's a good stopping place?

Aplan: That's a good stopping place.

VII RESEARCH PROJECTS

Coal Flotation to Separate Out Pyrite

Aplan: The first aspect is coal flotation, which has essentially been the major thrust of what I've done there. I've had a lot of my students work on that. When I arrived here I had to cast around for a niche to work in--you know, put my own stamp on it--and I found that there wasn't much in coal flotation going on worldwide. There had been a very active [program] at the University of Leeds in the U.K., particularly in the fifties, but that was pretty well winding down. In the U.S. [there was] the work that had been done at the Bureau of Mines at Seattle, [but] they were closing up that station, so that was ceasing. Here at Penn State, Dr. Sun had been very active, particularly in the fifties, but his more recent activity was more modest.

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Swent: We're continuing after a lunch break. You were just beginning to talk about Dr. Sun and coal flotation.

Aplan: This is part of the coal flotation. Dr. Sun had come to Penn State just after World War II and he was very active in coal flotation work, particularly in the fifties. In 1954 he published two really classic papers. And if you're doing any work in coal flotation, sooner or later you're going to refer to those two papers. His research work was more modest in the sixties, though the work that his student, John Campbell, did on zeta potential of coal and Ken Savage and George Wen did on coal flotation are important pieces of work.

My work at Carbide--and as the environmental movement was starting to get going --we're talking 1968--the rejection of pyrite from coal began to be an important feature. Most U.S. coals have some pyrite and of course if it isn't removed it goes up the stack as SO_2 and they don't like SO_2. I considered coal flotation rate to be an important parameter that could be used to help separate pyrite and ash minerals from coal. That is to say, the coal floats faster than does the pyrite and so if you arranged to remove the material

quickly then it would be enriched in coal and impoverished in pyrite.

There had been some extensive work in coal flotation in the fifties, particularly at Leeds University in the U.K., but for them they were just looking at the flotation rate of coal since there wasn't much problem of pyrite in the English coals. They hadn't really stressed pyrite, so this was kind of the little void that I wanted to fill. In the U.S. there was essentially very little work being done in coal flotation by anyone except for that work being done here at Penn State. The Northwest Experiment Station at Seattle--the coal station for the Bureau [of Mines] was phasing out. And for ores there had only been a modest amount of flotation rate work. Schuhmann at MIT had done some work about 1940 and in the fifties and early sixties, Tom Morris--at that time at the University of Missouri-Rolla--and Nat Arbiter at Columbia had done some work, but these people were dealing with ores. And after they stopped their work, no one else seemed to consider that an important parameter.

My first M.S. student was a student by the name of Rastogi from India, on leave from the Indian AEC. And in the period of 1968-70 we did a lot of experiments and showed that rate was an important parameter and could be used to discriminate against pyrite during coal flotation. All total, in the area of coal flotation I've had something like sixteen students, most of them at the M.S. but a couple on the Ph.D. level.

Let me stop with a little sidebar here: most of the time while at Penn State I have stressed the production of M.S. level students rather than doctoral level students and the reason is that the U.S. industry needs a lot of development engineers. They need a broader education than you can get at the bachelor's level. And this has been particularly important since a few years after World War II when metallurgy became much more compartmentalized than it ever was before--then switching over to material science. And students weren't as broadly educated. A typical metallurgy pre-war and immediate past post-war metallurgist could handle mineral dressing, hydrometallurgy, pyrometallurgy, physical metallurgy. Today that's no longer true. There are subdisciplines and so you just don't have one person who can handle that all. So now that puts the emphasis on the M.S. to do these things. And what is really needed in the way of engineering by industry, in my opinion, is an M.S. development engineer. He needs a broader experience than a B.S. level engineer, but we need a person who will make it work. Somehow or other he has to bring all these talents to make that thing work. There is a crying need for those people.

In coal flotation we looked at almost every conceivable aspect of coal flotation. We evaluated pyrite rejection, ash rejection, and the response of locked particles. In other words, a particle that's part pyrite, part ash, part coal--how does that respond to the system? What's the effective particle size? What is the nature of the ash constituents in coal? There's a lot of different minerals in raw coal other than just coal. A major one is clay--what is the effect of clay? There are different types of clay--and what's their influence on the flotation of coal?

What are the properties of coal pyrite? Coal pyrite is quite different than ore pyrite.

We've done some extensive work on this, and we found just using a simple thing like the xanthate flotation of pyrite from coal can be complicated. We studied maybe a dozen pyrites from coal sources and a dozen from ore sources and found that the ore pyrite floats typically 100 to 1000 times easier than coal pyrite does, so it's the same mineral but at the same time it's a different mineral. So the only coal pyrite that is even remotely like ore pyrite is one from an anthracite source and in anthracite it has been metamorphosed by being subjected to heat and pressure.

Swent: Well, now what is the difference?

Aplan: Difference in porosity, difference in the nature of the material, difference in shape, different--

Swent: Same chemical constituency, but--

Aplan: They are all FeS_2, basically. One of the big differences is that a lot of pyrite in coal was generated in situ--in other words, there was sulfur in the leaves and vegetable matter, and as it was coalified by heat and pressure, pyrite was recrystallized out. Often you can see pyrite from coal that has an imprint of a plant. You can see the structure of the leaf, or the structure of a twig or of a little branch, or whatever. You can see where it was generated. The pyrite was reduced by the carbon in situ. Now, this gives it a big porosity, a big surface area, and gives it much different surface properties.

We also looked at coal/pyrite separations by depressing the coal and floating the pyrite and vice versa. Because coal floats very easily, ordinarily we would like to float coal away from pyrite, but there is a process sometimes used in which you put in reagents to depress the coal and float the pyrite. And so we looked at various reagents, not only to depress pyrite, but we looked for reagents to depress coal. For the coal depression reagents, we probably looked at about 180 different reagents that could do it.

Then we also looked at circuitry variations and how changing the flotation circuit influences the separation. In ore flotation there's usually a fairly extensive circuitry of rougher, scavengers, several stages of cleaning, and sometimes a regrind, and a cleaning step; but in coal flotation, typically it's a straight-through process. The coal slurry is run into a bank of about five flotation cells and that which floats is good and then that which doesn't float is not and so it's a simple up or down process. So we looked at a lot of different circuits to see which ones would do the best job.

Swent: What was your relationship in all this with manufacturers or with industry?

Aplan: At this early stage, very little, though our initial work was soon sponsored by the American Iron and Steel Institute because they wanted to keep sulfur out of the blast furnace. Sulfur in the blast furnace ends up in the hot metal and they've got to remove that sulfur before they make steel. One of the principal ways sulfur gets into the blast furnace is from the coke and it gets into the coke from the coal, so if they can remove the sulfur

first, it will simplify things. So in those early days, most of my subsidization was from the American Iron and Steel Institute.

The American Iron and Steel Institute was a consortium of the steel manufacturers. About twenty-five North American steel manufacturers got together and on a tonnage basis they put money into the pot.

Swent: And were you competing with other people for these funds--with other institutions?

Aplan: Yes.

Other Coal Research: Quantification of Hydrophobicity; Oxidization

Aplan: Then we looked at the hydrophobicity of coal. Coal is naturally hydrophobic, i.e. it doesn't like water. And to float a mineral you want it hydrophobic; you want it to attach to an air bubble. If it repels water, it loves air, so you want it to have an air bubble attached to it. And the hydrophobicity of coal is determined by the rank of the coal. As you go from a very high-rank coal of anthracite through the various grades of bituminous, down to subbituminous and lignite, the hydrophobicity of the coal changes. And we quantified that. It's known that it changed as a function of coal rank, but to try and find good data was difficult. The English had done some work but the English don't have the broad ranks of coals that we have in the United States and so they hadn't investigated the entire rank system of coal--we did that.

Then there are coal constituents called macerals that are kind of like different minerals in an ore and they have all different hydrophobicities. They're all coal, but there are different coal constituents, so we looked at the hydrophobicity of those and how easily they float. This is important because one of the constituents is called fusinite and this often contains a lot of ash and often pyrite as well, so if you float it, it increases your recovery of coal but at the same time it increases the ash and sulfur content so you have to play a little game, a trade-off--how much do you want recovery against how much do you want a low sulfur, low ash product?

Then we looked at the oxidization of coal. Set coal out in a pile, it begins to oxidize. The various ranks of coal are related to their oxygen content. The oxygen content of anthracite is maybe 4 percent, the oxygen content of the bituminous is 10-15 percent, the oxygen content of subbituminous and lignite can go 20+ percent. So if I have a pile of coal and it oxidizes, the coal acts as if it were one of lower rank because it picks up oxygen. Even though it's a high-rank coal, it thinks it's a lower-rank coal. We looked at various reagents to float oxidized coals and the low-ranked coals, and for that we've looked at I think 160 different reagents.

We first did this by looking at three ranks of coal: high-rank coal, medium-rank-coal, and lower-rank coal. And then once we got a hit and we saw there were several reagents that look quite good, we then looked at eight different ranks of coal from anthracite down through subbituminous to see how they responded to these reagents. And that saved us from running 160 tests on each and every one of the eight coals. Then we also looked at other reagents that you could use to float the pyrite from the coal.

We did work on industrial flotation and circuit analysis and cell design. This was done by a grad student of mine named Barbara Arnold. And Barb did work in the lab, then took it to a pilot plant, then took it out into commercial plant, so she followed it all the way through--measured not only the performance but the kinetics of flotation, the residence time distribution in the cells, etc.

And then we also looked at the effective operational variables. How does the flotation cell ampeller speed interact with frother concentration? How does the amount of air you put in the cell interact with the amount of frother and the amount of oil you put in to float the coal? We've looked at all these various interactions.

Zeolites: Beneficiation and Ion Exchange Properties

Aplan: The next thing I've done quite a bit of work on are industrial minerals. The major work I have done in this area has been with zeolites. I've already told you about working at zeolites with Union Carbide. Carbide was no longer interested in the natural zeolites, so this was kind of an open sesame for us. In the meantime, Fred Mumpton, who had been the mineralogist working on zeolites at Union Carbide, left Union Carbide and became a professor at SUNY Brockport in New York and so we joined together. He was a geologist-mineralogist and he went in the field and collected a lot of these zeolite samples. We got some of the material that he collected and we started looking at the properties of these sedimentary zeolites.

The sedimentary zeolites have a different mineralogy than do zeolites from other sources. While there are about thirty some natural zeolites known, most major sedimentary zeolite deposits contain largely chabazite, clinoptilolite, erionite, and mordenite. These sedimentary deposits, interestingly enough, are usually close to monomineralic with resepect to zeolite species. If you have a deposit, it's often mostly erionite or mostly mordenite or mostly clinoptilolite, etc. You could have contamination of another zeolite with it from a couple percent to 20 or 30 percent, but most of them are predominantly one of those four zeolite species.

So over the years I had three students that worked on this. We looked at the beneficiation of these zeolites--how to upgrade if they need it, though many of them are quite pure as dug out of the ground. While many of them are close to 90 percent as dug

out of the ground, there are a number of other deposits that are only 50, 60 percent and in mining you have to sometimes take the poorer grade with the better grade. Some of these sedimentary layers--for example, part of the extensive Bowie deposit in Arizona over near Safford, Arizona--are only a few inches thick. So we looked at their beneficiation and developed both a wet and a dry process. Many of these zeolites are found in a very arid region, so dry processes may be important. We looked at the properties of the zeolites, their hardness, friability, porosity, specific gravity, surface area, et cetera. And there's a wide variation in these properties.

Swent: Who was interested in having you do this?

Aplan: Well, initially I started working only with what Mumpton could furnish me and what money I could scrounge around here and there and every place else, but then I got some support from Occidental Minerals. It no longer exists but Occidental Petroleum had a division on industrial minerals and they were concentrating on zeolites. The good thing about this is I had access to a lot of field geologists including Dick Olson whom I knew from Carbide. And they went out and collected samples for me. And then I got support from an organization in Denver that no longer exists called Resource Industries International. And so I got financial support from those two groups. But more than that I went from the half dozen zeolite samples I had from Mumpton to over thirty different zeolite samples from Idaho, Wyoming, California, Nevada, Oregon, New Mexico, Arizona--the whole intermountain area has these deposits.

Incidentally, on the Pine Ridge Reservation in South Dakota there are zeolites.

Swent: Really?

Aplan: Yes. You know the bentonite deposits up there at Belle Fourche?

Swent: Yes.

Aplan: They were formed under similar conditions--in other words volcanic ash falling into a saline lake--but with different conditions, and so you formed different minerals.

Then the other thing we looked at is ion exchange. You're familiar with the Culligan system?

Swent: Oh, yes. [laughs]

Aplan: In which case, they're using a synthetic ion exchange resin, but they once used a greenstone or a zeolite for that ion exchange. The exchange resin or zeolite is put in a sodium form using salt solution. To adsorb the sodium, then you exchange it. In the Culligan system, you're exchanging it for calcium and magnesium, which are the hard water constituents. When it has reached capacity you take it off-line and run a strong salt solution through it again and chase off the calcium-magnesium, putting it again in the

sodium form. Since zeolites also do that, we looked at a whole bunch of metal ions and asked how effective the natural zeolites are for doing it and what is the zeolite cation exchange capacity. For example, how much copper will it take up? Some of those natural zeolites are not stable in an acid circuit and yet for hydrometallurgical uses you may want to use something that is acid stable and so we looked at acid stability of these various zeolites. We also looked at agglomeration--so we've done an awful lot of work on these natural zeolites. We have eight or more technical papers published on these various aspects. Still not done. I still haven't published all the properties of zeolite.

Then I worked on limestone, particularly the dissolution of limestone by acid mine drainage. And when I get to environment in just a couple of minutes I'll talk about that.

Developing a Method to Increase Recovery of Oil from Shale

Aplan: Then—though it is not an industrial mineral per se, we looked at oil shale. You're familiar with the massive deposits of oil shale in western Colorado going into Utah. We had some money from Gulf Oil Company--later Gulf was taken over by Chevron, but when Gulf was still in existence and their research and headquarters were in Pittsburgh--we got involved working with them on the so-called R-5 property which was jointly owned by Gulf and Amaco. And in those days it looked like we were going to need the oil shale, and there are massive amounts of oil shale in the U.S..

Swent: It was a very hot issue at that time.

Aplan: It was a very hot issue, but the problem was that the oil shale as dug out of the ground ran about twenty to twenty-five gallons per ton of oil using a method called a Fisher assay. It's just a standard method for analyzing. People have tried floating it for decades and no one has ever been very successful. But one of my former grad students—R.S. Datta--who was working with Gulf at the time actually came up with a method of doing it so we expanded on the work that he had done. Once he came up with this technique and so we were able to take it from twenty-five to ninety gallons a ton. Now, in the standard procedure they take the oil shale and put it in a retort and distill off the oil. You see, by going from twenty-five to ninety gallons per ton, a lot smaller retort would be needed to handle the same tonnage because of the three-and-a-half times increase by beneficiation. And we got a high recovery--around 90 percent--but if we were willing to take a little lesser recovery, we could get up to 120, 125 gallons a ton.

Alternatively by using a higher grade feed stock a chemical plant could be used to extract the oil rather than doing it pyrometallurgically with a retort. Now, both pyrometallurgy and hydrometallurgy are fairly expensive processes unless you can use a cheap fuel or reagents. In chemical treatment we would have to use some organic solvents, so it would be fairly expensive. But if I now have the feed grade up to close to

100 gallons a ton, I'm only treating a quarter of the tonnage I would if I had to treat the raw stuff, so this looked good. Also in-house we developed a flocculation/flotation beneficiation process which we patented. About the time we got all this done, no one was interested in oil shale anymore. But it does--

We published several technical papers, and if they want to consider oil shale again, they will have to see what we've already done. If it's not of use today, maybe we'll use it tomorrow.

Finding Ways to Neutralize Acid Mine Drainage

Aplan: Then with regard to environmental problems--one of the first things we looked at was the use of limestone to neutralize acid mine drainage from abandoned coalmines and from refuse piles and so forth. If you have water and air present, it will convert the pyrite to sulfurous and sulfuric acids depending on the conditions so you will have acid leaching out and you will be putting iron into solution. Now, the iron solution then goes down the creek and when it meets another little creek flowing over limestone--and in Appalachia there's a lot of limestone--so when the alkaline meets the iron it precipitates the iron as iron hydroxide which is a slimy, red gunky stuff. Also some of the calcium from some of the limestone which is dissolved from the rock reacts with the sulfate coming from the oxidation of the pyrite to form gypsum, calcium sulfate. That whole mess is called yellowboy. And it's a slimy gunky stuff which lines the creeks and the fishermen hated it.

Swent: Is it toxic?

Aplan: Well, it--once it's neutralized it's not very toxic, but as formed it is a slippery, slimy mess, and then of course the acidic waters if not neutralized cause the fish to belly-up. So the idea is to get rid of the acid mine drainage. And I've already pointed out the work that Charmbury and the group here at Penn State had done to help remedy that.

But my concept was that since lime at that time sold for about twenty-five dollars a ton and limestone sold for $3, if I could substitute lime, the costs of neutralizing would be less. But the problem with limestone was that it would pick up a coating of gypsum and this gunky iron hydroxide on its surface. With this coating on the outside of the limestone and it wouldn't react any more. So the only way that you could use limestone would be to put it into some sort of a tumbling device, kind of like a ball mill or attritor to keep generating fresh coatings or, alternatively, take the limestone and pulverize it very fine.

Both of them are very costly and they reduce the neutralization capacity, so I had students looking at the dissolution rate of limestone--first of all in acid solution, then the dissolution rate in the presence of iron and aluminum, et cetera, just to see exactly what would happen. And we found there was quite a difference and that there was a fairly

narrow pH range in which you had most of the problems. Then we went a step further and did that with other ions in solution. This is also important, say, in heap leaching of ores or in dump leaching of ores because if the pH gets up a little too high, it precipitates ferric hydroxide. And that's that slimy, red gunk which will bind up the dump or cause channeling in the dump--you know, the solution that is supposed to be leaching the copper is going to take the line of least resistance so it's going to go where the gunk isn't, and you'll not get uniform leaching across the dump. So we started looking at how all kinds of other ions effect the dissolution of limestone. Okay?

Swent: And this had not been done?

Aplan: No. So we did dissolution rates of limestone under many conditions.

Identifying and Removing the Minerals in Blackwater

Aplan: Then we started identifying the minerals in blackwater. Blackwater is the solution containing the particles that remain in suspension discharging from a coal prep plant. Now, in earlier days a lot of that blackwater was discharged to a stream. Today the water is all recycled. If you tried to discharge it, you would be in trouble quickly. But whether it's recycled or not, you can't recycle a bunch of lousy, dirty water. You can recycle a little bit of it, but particularly flotation is very sensitive to the quality of the water recycled, so the idea is to clean it up.

We first had a student work on what is in the blackwater: how much coal is present, how much fine coal is there, how much clay--what clays are present, what other particles are in there, etc. Then we looked at means of flocculating that material. Then we noted, there's another problem. A lot of water contains fine particles and some kind of metal ion. And the usual method of removing the metal ion is to increase the pH by usually adding lime or sodium hydroxide and precipitate the metal hydroxide. So now you have a mixture of these slimy gunky metal hydroxides--I don't care if you're talking aluminum, iron, copper, zinc, whatever, their hydroxides are all slimy, gunky junk. And they're going to settle with the particles.

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Aplan: --so you've got fine particles and metal ion hydroxide precipitate settling. It's hard to handle, it doesn't filter very easily, it doesn't want to settle very easily; it's just a mess. So we worked out the techniques of treating different kinds of particles. We looked at about a dozen different particles: you know, different clays, quartz, limestone, iron oxide, titanium dioxide--all kinds of stuff. And we looked at about a dozen different metal ions. And different conditions. What you really want is that ore settled supernatant liquid--the liquid on top of the settled material should have a low turbidity. And among the EPA

[Environmental Protection Agency] specs [specifications] is turbidity, so you've got to meet that spec. Then you want to have a fast settling rate of the solids--the faster the settling rate, the smaller the thickener or settling tank or settling pond you will need. And then when it's settled, you want to have a high density of the settled sludge.

Now, when you evaluate yellowboy, or any other settled metal hydroxide combined with fine particles you find it's only about 3 percent solid; so it's 97 percent water. Now that poses a tremendous disposal problem.

Some scientists at Bethlehem steel developed a technique where they could increase the settled sludge up to 25 or 40 percent solids. That's a lot better because you don't have to have such a big disposal system. And we took that concept and generalized it to all kinds of metal ions. And for each metal ion there is a unique pH value in which you get the optimum results. We also looked at all kinds of flocculating agents and means of removing the sludge--you know, centrifuging it, pressure filtration, everything you can think of to try and handle this gunky sludge.

Improving Methods of Gravity Concentration of Ores and Heavy Media Separation

Aplan: Then the next thing I worked on was gravity concentration. First I wanted to continue some jigging work I had done at Union Carbide. Remember, I had told you that I had worked with jigging manganese ores in Guyana and jigging tin ores out in Thailand. In the latter case I used a full-suction placer jig. This is a jig that you would use on gold and diamonds--the kind that Norm Cleaveland used. Okay--a full suction placer jig. A jig has a pulsion and a suction stroke and for the full-suction they have diaphragm just below the bed and it sucks the heavy particles down through the screen and down into the bottom part of the jig called the hutch. So I said if I can remove cassiterite with a specific gravity of 6.0 from gravel and sand with a gravity of 2.65, then why can't I remove pyrite with a gravity of 5 from coal with a gravity of 1.4? And the answer is, you can. And so we found for the treatment of minus-quarter-inch coal, you can use a full-suction placer jig, and remove all the pyrite particles above 200-mesh with this jig. Then the recovery starts falling off for the smaller particle sizes, but even at minus-400 mesh, which is thirty-seven micrometers, you can remove 15 to 20 percent of the pyrite. And of course between 400-mesh and 200-mesh, there is a decreasing recovery of pyrite in that range. So here is a means of recovering pyrite from coal cheaply. We had some financial help on that from the Appalachian Regional Commission.

Then I worked on the heavy media separation process. Heavy media is a major method of concentrating coal. In the process you grind up magnetite, for example, very fine and make a suspension of it in water. You stir it a little bit to keep it in suspension--and it acts as if it has a higher density than water, so that you can separate the 1.4 coal from the 2.0+ refuse very easily by this process. And right now it's used--the heavy media

process and the heavy media hydrocyclone process are used to separate about 40 percent of the total coal processed in the United States, so we're talking in a neighborhood of over 200 million tons a year by this process.

Swent: Which had not been developed before?

Aplan: Oh, no. We didn't develop it. This had been developed years before and I won't go into all the history of it, but there was a similar process called the Chance Cone that the coal industry had used since 1920. And the ore people also used it, only they used ferrosilicon--ground ferrosilicon instead of magnetite. I had worked on that quite a bit at Carbide to separate chrome and manganese ores and so when I came here, of course I was going to use magnetite because I was working with coal.

But there are some problems with the heavy media process. It's quite good, but it could be more efficient than it is, so we looked at the effect of suspension contamination. You always get clay contamination from the ores or from raw coal. And we looked at particle settling in heavy media suspensions. We took weighted plastic balls and put a radioactive tracer in them. We dropped them in a vat containing the suspension of ground black magnetite. You can't see through it, but the gamma radiation can see through it. Using two counters we could determine how fast different balls could settle in the media.

Swent: So this was possible because of the new technology that was available?

Aplan: Well, heavy media has been used extensively in coal for forty years.

Swent: I mean this kind of tracer; that was new?

Aplan: We were able to do that part because of the radio tracing.

Swent: Which was new.

Research on Flotation of Copper Ores

Aplan: The next thing I've done is ore flotation. And since the principal ore we float in the United States is copper and because I once worked for Kennecott, I used copper.

This was a major project. We first started evaluating various reagents to collect various minerals. We looked at the major copper minerals: chalcopyrite, chalcocite, covelllite, bornite, and pyrite, and how they responded to various reagents. Now, most of the copper in the United States or in the world is floated with a reagent called xanthate. A smaller amount is floated with a Z-200, which Guy Harris developed--(Guy Harris has worked with us--and he's presently been working with Doug out in Berkeley--and I'll have

more to say about Guy in a minute)--and the aerofloat-type reagents that Cyanamid made. But we looked at a total of 110 chemical mutations of reagents that we thought would be good.

I was aided in this by Dick Klimpel--R.R. Klimpel, who at that time was working for Dow Chemical--and by Guy H. Harris. Klimpel was in charge of some of Dow's mineral research and Harris had been the synthesis chemist for Dow at Walnut Creek for umpteen years. He was an old-line organic chemist. And old-line organic chemists has a head full of knowledge. They were walking encyclopedias. And Guy, who has been . retired for ten years at least and is still a walking encyclopedia. And what reagents work--and so we looked at 110 of those reagents.

I also had a real advantage. One of the undergraduate students in mining had taken my course and his sister was taking a double major in chemistry and biochemistry. And at that time in our biochemistry major they spent almost the entire senior year in the laboratory synthesizing reagents and doing chemical operations. So Patrice Ackerman heard about me from her brother and she walked in to see me. I almost said, "Come into my parlor said the spider to the fly," because I had been looking for someone who could synthesize reagents and perform the other experiments and she had the ideal credentials for that. We then contacted Guy Harris. Guy would come in for a few days or a week or so and help with the synthesis of reagents. So together they synthesized maybe twenty-five, thirty reagents, she synthesized another dozen on her own, and then we had access to Dow's K file of the reagents that Guy Harris had synthesized over his professional life. They kept small samples so we were able to look at about 110 different collector reagents.

When we got through we found several that were very good and I was pleased as punch with myself and with all of us. Then I got a dose of reality. What had happened by the time we finished is that the various governmental health organizations had tightened up the specs and now they required that if you made a new reagent you have to test it out on the mice, the rats, the cats, the dogs, and finally the humans. And the cost of doing that is massive.

Now, even if I had a wonderful reagent, the whole mining industry doesn't use that big a tonnage. For example, in copper flotation we use 0.025 pounds per ton of ore treated, so at the end of the year even though I may have a 100,000-ton-a-day operation, there's not that many tons of that reagent. And the profit isn't that great. An older reagent has been around for a long time and anyone can make it may be better. My new reagent would cost too much to go through all that testing to have it certified for use in an industrial environment. So when we got through with all this I learned the hard facts of life. And even though I maintained I'm a practical individual, I wasn't that practical--but I'm a lot more practical today than I was before.

Swent: Oh, what a pity.

Aplan: But we did learn a lot. We learned a lot. And this resides in the literature, so it wasn't a

total loss.

Klimpel had headed up Dow's corporate operations research group. He was a first-rate engineer and was well-versed in all kinds of things such as operations research, expert systems, statistics--for his master's he had majored in statistics, and on and on. He got his doctorate here in our department at Penn State in the early sixties, then went to Dow, so there was always a good liaison with him. Klimpel, incidentally, later president of SME.

Swent: Yes, right, I remember that.

Aplan: And so we started looking at some other things. I'd been doing a lot of work on flotation rates of coal, so we just went over and continued this on copper ores. That was later extended into operating plant. Ed Dowling, whom you met, was doing this as his M.S. and Ph.D. theses work. He went into the copper mill at Pinto Valley, Arizona. At that time Newmont owned Pinto Valley, so we had a good liaison with Newmont: for example, Len Harris and Bob McDonald--and so we had access to that plant. One of the problems is usually that if you come to a plant they say you're a pain and, we don't want you messing around with our plant, but in this case when the corporation says, "Won't you help these people out?"--they are very helpful.

Swent: Yes.

Aplan: Actually, the people in the plant were most helpful. And so we went and sampled that entire circuit--the entire copper flotation circuit at Pinto Valley. And we've gotten several publications on this.

Then one of the things we were interested in is a detailed sampling of a copper concentrator in order to get enough good rate data on a cell-by-cell basis. It's a long laborious process and so we wanted to see if it is possible to take small samples almost instantaneously. In other words, in five seconds you've got your sample.

Now the plants have massive flowstreams. As you know, a 50,000-ton-a-day ore concentrator will pump 35,000 gallons of water a minute through that plant. So, it looks like Niagara Falls in volume. And we wanted to see if you could take small grab samples and flow rates and by making use of linear programming and the analysis of error be able to specify what is happening in that plant. If someone wants to know, "How is the scavenger cell circuit working?" you could pull up the computer information and find out immediately a projected value. That's a lot easier, so we did this. And on two different shifts we sampled the whole plant and then have compared that data to a month-long laborious sampling that Newmont had done. And it turns out that by using statistical analysis and linear programming you can do it. And so you can get a good estimation of what is happening in your plant with a few on-line sensors and software to give you projections of that circuit, what the flows are throughout the circuit, what the copper values are throughout the circuit, what the recovery is throughout the circuit--the whole thing. And that's a lot simpler.

Swent: Yes, indeed.

Aplan: And that's in Ed Dowling's doctoral thesis.

Swent: Which he did here?

Aplan: Yes. In that case we had an industrial cooperative program, we had money from the National Science Foundation, help from Dow based on Klimpel's time and access to all kinds of reagents, plus Newmont's help, so it was a consortium that actually did that work.

Swent: And that's the thesis that he's presenting this afternoon?

Aplan: Yes, yes. Now most of that has already been published over the years; he's just putting it together as a thesis at this point. He has done some extra work industrially to add to it, but it's based on work that we've done over the last decade.

Other Research in Flotation of Minerals

Aplan: Then, in terms of general things, sometimes you want to do some fun things or sometimes you're interested in something you ought to do. And one of my colleagues in metallurgy is George Simkovich, and George specializes in point defects. Many minerals--essentially all of the sulfides and several of the non-sulfides: horn silver (silver chloride), fluoride, hematite, magnetite, etc., are natural semi-conductor minerals.

There are two things that influence their electronic properties. Number one are vacancies. In a crystal lattice maybe you've got copper-sulfur-copper-sulfur-copper-sulfur-copper-sulfur in a three-dimensional lattice--Mother Nature goofs up and either does not put in a cation or does not put in an anion someplace in the lattice. Or you may have an interstitial ion in the lattice. This can happen in two ways. I can induce that synthetically or Mother Nature can sometimes induce it. For example, one 1/1000th increase or decrease in sulfur in the mineral galena will change it from a P [positive] to an N-type [negative] semi-conductor. In the old days when you used a crystal radio set you only could use certain galena samples because you had to have the right semi-conductor type. We didn't know that at the time, but that's what it was.

The other thing that can happen is that you can have a replacement ion. Let's say I had something like nickel oxide. Nickel has a valence of two, but if I substitute for the nickel, the ion of lithium, it has a valence of plus one, so now the structure a charge deficiency of one. I can also put in chromium-plus-three and now it will have an excess of plus charge--and so you can play a lot of games like that with minerals. Mother Nature does it all the time, so you can get these minerals in nature and sometimes they're P and

sometimes they're N-type semi-conductors.

We have made use of that in electrostatic separation. I've done a lot of electrostatic separations--particularly on that dry plant for the tin dredge--so I was well familiar with electrostatic separations. And you can make massive differences in electrostatic separation depending on the nature of the mineral which we have quantified and published.

It also affects the flotation of the minerals. A P-type semiconductor acts differently than an N-type semiconductor in the flotation process--sometimes subtly, and sometimes massively. There are five different types of these point defects and I'm not going to go into that--actually, theoretically there are six, but we find five of them in nature. And all of them influence the flotation of the minerals and so we looked at that. That was sponsored mainly by the National Science Foundation.

Another thing I've looked at is locking. And of course we were greatly interested in coal. In specific gravity separations, we can take off the lowest specific gravity material as good coal, or take off the highest specific gravity material as refuse, and then I have the middling in between. And that middling particle is composed of coal particle with maybe some attached ash or pyrite. There are called locked particles. So my concept was we should focus on these middlings. So we purposefully made specific gravity separations to produce only at that middle gravity group of particles. And we looked at how they responded to different types of crushing devices, under what conditions you best liberated the pyrite, because if you're going to separate the pyrite from the coal, you first have to liberate them, then separate them. Pyrite has to be a discrete entity and the coal has to be a discrete entity. This was also sponsored by the National Science Foundation and the Appalachian Regional Commission. And we ended up with a very simple model to describe that process. Now, there are much more sophisticated models, but this thing is simple so you can do that in thirty seconds on a hand calculator, so that's helpful.

And the last thing I've done that I can think of at this time is ion and precipitate flotation. If you want to clean up metal ions from water there are a couple of ways you can do it. If I had, for instance, copper contaminating water, I can add a detergent or a soap and attach that to the copper ion and float it out of the system--put in some bubbles and take it out on the bubble. But that method has a defect. Most of the metals we're dealing with are divalent. Copper, for instance, typically will have a valence of plus two. This means that it takes two moles of the reagent for every one mole of the copper. Let's say we're using a soap: then we're using two soap molecules to recover one copper molecule, okay? Because soap has a valence of one, you need two of them. That's pretty expensive. But if I take the copper and precipitate it as a hydroxide or a sulfide, now I have a particle of hydroxide or sulfide and I can add just a little bit of reagent to hook onto that so-called particle. Consequently I've reduced the reagent concentration massively. So we looked at that process and how you go about doing it.

The next thing I want to talk about--

Swent: Let me just--you know I'm not a scientist, obviously, but some of these things it seems to me you were able to do because of your particular personal experience that you could--for instance, bringing tin experience to bear to something else. And some of them, I guess, were possible now because of techniques--technology that hadn't been available before.

Aplan: And also because of colleagues. I mentioned Simkovich, I've mentioned Klimpel--we have several of us here in mineral processing—Austin, Chander, Hogg, Osseo, Klima, Ityokumbul, we have a wonderful opportunity to pop in next door and run an idea past one of your colleagues. It takes a critical mass, actually, to do some of these things effectively. I mean, if you try to do it all yourself, sooner or later you're going to mess up.

Swent: That synergy was important.

Aplan: If you can talk to someone and run it by them--and if you don't know the technology, go find someone that does. Why do you spend six months of your life studying in the book for all that technology when all you have to do is simply visit the next door or next building? It takes me five minutes to walk over to say Simkovich's office, that's including walking up the stairs. He's on the second floor, so within five minutes I can get over there. Or I grab the phone and buzz him.

Klimpel was an adjunct faculty member here and so he would be in every month or two and so we could talk to him, or I would get on the phone to him. So people, I guess, were the biggest thing that helped me--some of my ideas helped me, some technology helped me, but mostly the technology helped me because the technology had often been around quite a while in some other field but I was just too dumb to know it. And I will talk about that a little later when I get to professional societies--how you learn about some of these other technologies. But that helps, as do colleagues. And if you don't know it, the most efficient way is to work with someone who does know it. As I've said Simkovich and Klimpel were for me beautiful examples of that. And Guy Harris, who came in with his head full of knowledge on all of these chemical reagents because he spent his entire life in Walnut Creek, CA doing that--he started with the old Bear Brand which later became Dow.

Funding of Mineral Processing Research

Aplan: Let me talk a little bit about philosophy. I've already spelled out some of my philosophy of life as I've gone through these various talks, but basically I'm attracted to practical problems. You have to think about what is necessary in order to solve these problems. And this puts mineral processing at a real disadvantage. In chemistry they can do basic knowledge and then you've got a chem engineer who can use that fundamental knowledge and doesn't have to go back and do it all over again because it's already in the chemical

literature. Engineering mechanics and physics provides a lot of info, so the civils, mechanicals, aeros, electricals--all make use of that. But in the mining fields we don't have any dedicated counterpart so a lot of times you have to go in and do the science yourself. You have to do enough of the science to solve the problem. And so most of us in this industry have been pretty broadly educated. We've taken a lot of courses in chemistry and stuff like that so we're familiar with some of these techniques from these other fields. And you know, it helped me that I had a good background in chemistry. I was able to get a good education in crystal chemistry, for example, and that stuff helps in solving a problem.

Swent: It seems to me you're getting into physics a lot, too, aren't you?

Aplan: Yes, but that isn't as serious. And the reason--this is a bias on my part, okay? The reason is this--

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Aplan: You had asked me about use of physics.

Swent: Yes.

Aplan: That isn't as serious in my opinion. And the reason is that, starting in the mid-fifties, the physicists went off on an atomic physics kick and they dumped classic physics. In some places it was so serious that the engineering colleges put in their own physics department--classic physics department--in the college of engineering. Now, classic physicists can handle mechanics, heat, light, sound, et cetera, like no one you've ever seen. They are superb. But some of these modern physicists, they don't care about heat, light, sound, electricity, and that stuff. They don't care about that and they're not interested in doing it, so physics hasn't been as helpful, whereas chemistry in the meantime has continued to grow and grow and grow. When I took organic chemistry there were something like 250,000--this is 1942--there was something like 250,000 organic chemicals known. I don't know what--it's in hundreds of millions today. So they've grown, and grown, and grown. And also because there are only a few people in my profession, we have to be quite efficient. You know, we can't worry out every little detail or you would never get anything done.

Now, it is my feeling that our industry has taken several beatings. National Science Foundation, their engineering division closed out most of the mineral areas, so we couldn't get funding there. The Bureau of Mines was folded up. The Department of Energy has been on a non-practical kick, so we can't get much money out of them many times. And, quite frankly, they often work on the buddy principle--sometimes dictated to them from Congress, but a lot of times internally. They've got the buddy principle and if you're not a buddy, you don't get anything. Industry has done precious little for us in recent years. And it has gotten worse because most of the companies have closed out their R and D lab. The Cyprus-Amax lab, that's gone. You know, it just goes down the line. You name the

company--those old research labs are gone. Kennecott's research lab was totally wiped out and now it's not even a good-sized shadow of its former self. And you name the company, they've gone through and cleaned out their research group. There is also less plant-type research done because as the blood-letting has gone on in corporations they've stripped down the operational personnel. And the people they have left are spending most of their time putting one foot in front another solving day-to-day problems. They haven't got any time to be thinking of longer range--

Swent: No.

Aplan: I've taken a number of field trips and I've seen some industries in which it's just a total rat race. The company spent too much time with the New York Stock Exchange. And they want it to look good, but in the long range it's going to cost them, because to maintain a couple of development engineers or a research scientist isn't going to cost you that much money.

And my proposal is this: many of the mining executives have properly observed that they're not getting what they want out of some of the universities--and I won't go into all the reasons for that-- There are quite a number of reasons for that. For one place, the university does research where the money is and the government is where the money is, and so if you want to survive you have to do the research that government wants you to do, which isn't necessarily the most important research that you could do, or the research which you have the greatest talent to do. And so a lot of important research doesn't get done.

I've been trying to sell this concept.

Swent: Well, you've done some writing on this topic.

Aplan: Oh, writing! Yes, but people often don't read what you write.

Swent: Well, you were writing to the--preaching to the choir as they say.

Aplan: Yes. So what I propose is this, that a company determine what their problems are. And that should be a two-fold operation. They should look at their own operation and ask their own people--starting with the operators, you know, everyone in the plant. A lot of those operators have got a head full of knowledge. They may not know what caused the phenomena, but they have logged the phenomena in their head. When I've worked in plants I've always made friends with the operation crew because they know a lot more about that operation than I'll ever know, but a lot of them don't really know that they know it. It's in the back--

Swent: It's not scientific--

Aplan: No, it's in the back of their head someplace. They made this little observation and didn't

think anything of it. But if you can talk with them a while then they suddenly say, "Yes, yes, I've seen that," and then can expand on it, whereas if you had asked them to write down everything they see, they wouldn't put that down because it's logged way back in the far reaches of the mind. So companies should go through their own operations and indicate where their problems are.

Then they should bring someone in from the outside to have a look-see. There are only a handful of consultants that I would bring into my plant. We've got a few people in our industry who are really good--really good consultants--and I would go get one of those. Sometimes you get tunnel vision. You get too close. You can't see that you've got a forest here because there are trees there in the way.

Swent: And personalities.

Aplan: Yes, of course. All these things. So now that they have been able to delineate their problems. They should bring in a half dozen professors whom they are going to select with care. You know, there are good faculty members, there are bad faculty members, there are medium; there are indifferent, there are those that know your field well, and those who are excellent people but who don't know your field. There's all combinations. There are people that have some extraneous knowledge that isn't a part of the problem itself but if you had really studied the problem--you knew that you needed this extraneous info, or maybe you want to bring someone in from some other field.

I know one case where one of our meteorology profs classically trained in physics was brought in to solve a problem of a corporation because he knew this specific area of classical physics which everybody else had forgotten or had studied these things maybe as a sophomore as college and then had forgotten.

So you bring in this select group of people and you present the problem to them. And then you say, "I've got X dollars to fund one or two projects dealing with this--I invite your proposal." The company must then have a good project liaison. A corporate staff person is going to check on that project every few months so that the professor doesn't run off and do something else, but this must be done carefully. The worst thing you can do in industry is to try and dictate to a university--that's a treadmill to oblivion. But this way you can have your cake and eat it, too. You can keep control of the type of project, you don't need to tell the professor what to do because you know what his specialty is, and you know that he'll go ahead and do this. That's what you want. I think that's what they ought to do and that's the most efficient way to do it.

Australia's Commonwealth Scientific and Industrial Research Organization

Swent: And is it being done that way at all?

Aplan: I saw it being done out in Australia. Now, they've got a little different situation. Most of the Australian coal out of Queensland and New South Wales goes to export. A lot of it--coking coal--to the Japanese. And the country puts a tariff or a fee on that coal. Every time they export it, so much goes into the kitty and they have this kitty of money.

Then they have an organization of experts representing a lot of the coal companies that put the money in the kitty and then they prorate their money out to the universities or consultants to industry or CSIRO, which is Commonwealth Scientific and Industrial Research Organization. It's kind of like we had in one organization the Bureau of Mines, the Geological Survey, and the agricultural research--governmental agricultural--if that were all in one organization that would be roughly CSIRO. And so CSIRO also bids on these projects. Actually, many of them are wired ahead of time because industry knows the strengths of those people. And for years, the American Iron and Steel Institute did this, and all that money didn't go to universities. A lot of it went to certain companies. Maybe Bethlehem Steel was doing something different with the blast furnace so they would get some money too, because what they learned from the blast furnace would aid all the members of the group.

And the Australians have regular meetings. They have yearly or more frequently show and tell--where the researchers have to get up to tell what they've been doing, why they are doing it, and show them the data, and take the abuse if the people think they are doing the wrong things. So we could have something like that.

Swent: Didn't the Bureau of Mines do something similar, or was supposed to?

Aplan: The closest--on record I don't want to get into the Bureau of Mines politics, okay? [laughs]

Swent: Okay.

Aplan: The closest they came to doing that is they had some of the university research centers. But not all of them were selected with the greatest care or with the greatest source of expertise. There are two of them that did a tremendous job--and I won't tell you which two because then my friends in the others will hassle me, but that's all gone now. So it didn't make any difference. But the Bureau basically didn't spend enough time generating friends during the good years. You know, I know people in the industry who say, "Ah, so they're gone!" [slaps leg] Now, if the Bureau had paid a little more attention, they would have had some guys pounding down the doors in Washington.

Swent: Yes, it went under without much commotion at all.

Aplan: Without much. They should have minded their P's and Q's, particularly in the last few years. That's an opinion--may even have been a fact.

Swent: But this has left a hole?

Aplan: It's a hole. But anyway, I think that my proposal is a way to solve the problem.

Then, going on with the philosophy, what is an engineer? Well, I guess the first definition of an engineer is one who thinks he is.

Swent: [laughs]

Aplan: It's kind of an aura, a way of life, something. I've heard this definition: you do the best job you can under the constraints imposed. You've got constraints on the dollars, constraints on the location, constraints on the personnel, constraints on the time, constraints on the materials, etc., but somehow you have to do it. I could build the Golden Gate Bridge a lot simpler across Bald Eagle Creek here in Pennsylvania, but they don't want it. They have a specific location where they want the bridge built. But there are all these trade-offs.

And then Dave Swan had a good definition. He was vice president of Carbide--he had been director of research in the Electromet lab I told you about, then he became vice president of research at Carbide, then he went to Kennecott as vice president of research, and subsequently I worked with him extensively when we were on the Engineering Foundation Board of Directors. So I got to know Dave quite well. He said the difference between the scientist and the engineer involves these trade-offs and the degree of certainty. We've already talked about these trade-offs, and as for the certainty, sometimes it absolutely can't fail. Well, in reality we can't always pour all the money in to have all the redundancy that we have in the space-age program. Some of them you have to say, well, I have to accept the fact that there will be some accidents. But you have to be careful in doing that and it involves a tremendous amount of judgment. And the engineers that make that judgment are people to really be respected because they have--well, you saw that in your own professional situation. Your husband had to make those decisions thousands of times.

Swent: Yes.

Aplan: And a lot of those times you don't like to do it. You don't like to let certain personnel go but you've got this dollar constraint and it has to be done. You have to do a little slap-dash job on this job because some other job is much more important. And you've got all these trade-offs. Then, when you get to a college--we have college of science: they do mostly fundamental things. In the college of engineering they do practical things, but even here they often deal with very homogeneous materials. I spent many years at Carbide working with some of the chem engineers and when they first got introduced to minerals, they thought everything was reagent-grade material--coming out of a bottle, you know.

Swent: [laughs]

Aplan: If someone told them that the formula of a mineral was such and such they thought that's

what it was, not realizing that a lot of minerals are just junk heaps and they've got everything in them. We've already talked about chromites.

And then in our college--EMS--we deal a lot with natural products. I mean the geography department deals with cartography, and they do a lot of studies of why people go to cities and why they move to suburbs--this side of thing.

Our meteo department has to deal with the change of the weather all the time. The geology department's got natural products, mineral engineering has natural products, and material science has natural products, so it's often much more difficult because nothing is really pure, nor is it constant. The ore grade changes day to day coming out of the mine and yet the reason it changes is because they have to mine in a certain sequence. Because they can't be sending a 150-ton truck back empty--when that truck's loaded and has to come back now. So this college has historically dealt with applied things. And as I said, mineral processing and mining and so forth have always dealt with the real world.

Family Life

Aplan: Let me talk a little bit--as long as I'm at Penn State, let me talk about some of the personal things at Penn State. My three children largely grew up in State College. The oldest daughter, Susan, graduated here at Penn State--I told the kids originally they could go to any school they wanted as long as it was Penn State because I had a big discount on the tuition. She took a degree in phys. ed. and athletic training. The athletic trainer, worries about preventing athletic injuries and then if there is one, making some quick adjustments for the injury. She's now a school teacher in the northeast part of Pennsylvania. She teaches phys. ed. in a grade school and then is the girls' track coach at the high school.

Swent: Is she married?

Aplan: Yes, and she has two children.

Swent: What is her married name?

Aplan: Susan Bower. And she has two children.

And our son Peter, went to PSU--I told him at that time he could go to any school he wanted to as long as it was Penn State, unless he chose metallurgy. At that time I was head of metallurgy and decided, "You're not going to come to the same department as I am in." I told him, "You could go to Colorado School of Mines or Carnegie Mellon or Rapid City or someplace, but you're not going to go here." Well, it turned out, he started out in chem e. and then became very interested in biology. He ended up in biophysics, which worked out nicely because when he finally finished with med school, he has done a lot of

research work in molecular biology, so he knew those techniques long ago. He did his M.D. at Hershey Med School, which is Penn State's. He then did three years residency at Buffalo Children's Hospital plus a year as chief resident--then five or six years with National Institutes of Health in their pediatric oncology branch. And so he's a pediatric oncologist. And he's now back in Buffalo. He works at a cancer institute called Roswell Park. It's both a cancer hospital and a research institute. And then he also works out of Buffalo Children's and is also on the faculty of the University of Buffalo Medical School. So he does about 80 percent research--mostly in molecular biology of childhood cancers--and about 20 percent clinical.

Youngest daughter Lucy didn't want to go to college. She ended up down in Myrtle Beach as a hair dresser and finally decided that was a treadmill to oblivion and so she went to the local college--it was a branch of the University of South Carolina--now it's a separate college called Coastal Carolina--and took marine science. She has always been interested in marine life, particularly dolphins, and so she graduated, past the age of thirty, but she is really motivated. She had to go back and take a lot of make-up and worked like a dog. And so I'm very proud of what she's accomplished. She's working in the nature program operation near Charleston, South Carolina. I should call it a nature walk, but it really isn't a walk because a lot of it is done with canoe. They go out and look at the turtles and the porpoise and the alligators and so forth.

I've had a couple of bouts with cancer and I'll talk about that later. Let's start on the Engineering Foundation even though we won't finish it.

Swent: All right. [tape interruption]

There's this one question; you started here as --

Aplan: I came in as department head and full professor. When it was changed to a section--we first were under the department of material science, and I was section chairman of mineral processing. Then we had some problems in metallurgy so I had the arm put on me to take over metallurgy. And I worked like a dog on that and was very fortunate; I got cancer, so I got out of that job.

Swent: [laughs]

Aplan: So in the thirty years I've been here I spent ten as an administrator. But the top of the line in the university is not section chairman or department head or a dean; the top of the line is a full, tenured professor with his own access to money and his own reputation. That's the top of the line.

Swent: And a parking space?

Aplan: Oh, yes, and a parking space.

Swent: [laughs]

Aplan: Well, when I first came here it was much easier to get a parking space. And then of course I retained it as I went through the system. But I've enjoyed my stay here and I will discuss that a little more a little later.

Swent: Okay. [tape interruption]

VIII PROFESSIONAL ORGANIZATIONS ACTIVITIES AND AWARDS

The Engineering Foundation

Aplan: The Engineering Foundation in New York City is a division of the United Engineering Trustees. And the United Engineering Trustees was put together by the five founder societies. Initially it was AIME, ASCE--the civils, ASME, the mechanicals, and IEEE, the electricals. And then a couple of years later, AIChE--the chemicals joined, so the five founder societies had representatives on the United Engineering Trustees.

Under the United Engineering Trustees was the Engineering Foundation and then they used to have the Engineering Society library in New York. That has since been dispensed with. I think it's out in St. Louis now. It was a big financial drain, but it was a magnificent library.

This has historically been in the United Engineering building in New York City--345 East 47th, which is just adjacent to the United Nations Plaza. We'll discuss later--the building has just been sold. It's going to be torn down and Donald Trump's going to put a big high-rise condo in there.

The Engineering Foundation was the interdisciplinary research and conference arm of the United Engineering Trustees. It has its own board of directors: two directors from each of the societies, plus a couple of directors at large, and then a couple of directors representing the UET--United Engineering Trustees. It was founded in 1914 by Ambrose Swasey who was an engineer and also an entrepreneur. He originally gave a gift of $200,000 and then in the next few years he gave a total of $840,000. Now, in the pre-World War I era that was a good piece of pocket change.

Swent: Oh, my, yes.

Aplan: He had made his money making precision instruments. And he ended up doing a lot of the astronomical observatory instrumentation, but his instruments were mostly winners and so

he made quite a bit of money.

The board of directors at the Engineering Foundation, as I mentioned, has two members from each secretly with a chair and a vice chair.

They've had two major thrusts. One is the Projects Committee and the other is the Conferences Committee, and I'll talk separately about both of those.

Let's talk about the Projects Committee first. They are interested in interdisciplinary approach. If they do something that's mostly one society, some other discipline must make use of the information or they won't fund it. So it has to have some interdisciplinary aspect to it. Now the interdisciplinary doesn't have to be with another founder society--it could be with the industrial engineers, who are not members or the aeronautic engineers, who are not members; or it could be with the biologists or the chemists or whoever. But the watchword is interdisciplinary.

It started in 1916 with grants and since that time they've had about 250 projects. Now, in about 1970, the National Science Foundation and other government sources massively increased funding to the universities and to private research groups and so the Engineering Foundation started changing their research. And I will talk about that in a second, but with the initial 250 projects, you can realize that even a small amount of money in 1920 meant a lot because the universities received no money for research and stuff like that.

And only a few schools had any graduate programs, but the AIME recipients worked on things like metal fatigue, corrosion, thickening etc. That sounds like the mining or metallurgy, but chemical industry does a lot of grinding of plastics. And agriculture grinds an awful lot of grain and not only for flour but for chicken feed, etcetera, etc., etc. And as for the properties of metals, of course most engineers, civils, electricals, mechanical, metallurgical, want to know the properties of metals, so they were interdisciplinary. The examples I gave were a few projects of the 250 that kind of related to AIME things.

As the funding increased--the money for this came from our endowment and of course as the stock market got better, they had more money and they could do more things. The Foundation also developed the research initiation grants where they would give, say, $20,000 to a relatively new professor. There were constraints—the faculty member could only have been on the faculty for five years. And there were other constraints to help someone new get started. Because a new faculty member can't just write a proposal to the National Science Foundation or someone else and get funded. You have to have some data and you have to show that it has a good chance of success. Where are you going to get the money to do that? And what the Foundation did in the period of 1977-97 was to initiate over 300 of these things. So this helped a lot of people get started. They would give typically two grants per society per year, so there would be ten plus a few extras. And they were very competitive. Often we would get forty, fifty proposals. And when I

was on the board of directors, I served on this committee and I later was vice chair and later, chair, both of which served on these committees, as well.

The other committee they had was the Conference Committee. And again, they found that there was a need for interdisciplinary conferences crossing various boundaries and so that's one of the watchwords.

These conferences started in 1962 and to date there have been about 800 of these, so it was a big operation. In the first five years there were only about twenty total, but since then there's been roughly twenty-five per year--sometimes a little lower, sometimes a little higher. And the conferences really got a shot in the arm in 1966.

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Aplan: They got a shot in the arm in 1966 when Dr. Sanford Cole joined as Conference Director. "Sandy" had been Director of Research for National Lead. And on retirement he took it as a part-time job, but he really put his shoulder to the wheel. He went around putting the arm on people to get these conferences really working. And it was really truly a work of love on his part because he really moved the thing.

Sandy, incidentally--I'll get a little PR in here--had taken his doctorate at Penn State in ceramic engineering. And it was one of the first doctorates given by the school, or maybe the first doctorate in ceramic engineering.

Sandy pushed, pulled, mothered, whatever to get the thing going. He was replaced on retirement by Harold Comerer and more recently by Richard Freiman. The latter two also took on the additional job of Director of the Engineering Foundation. Cole was only Director of the Conferences and part-time, but he had those conferences so well set up and everything organized and well with strong committee members who would come up with ideas, that it really worked fine.

Let's stop there because--

Swent: Okay.

The National Academy of Engineering

[Interview 4: July 23, 1998] ##

Aplan: We had been talking before about the Engineering Foundation. Perhaps the greatest impact that the Engineering Foundation made on the profession was its key role in founding the National Academy of Engineering. Engineers have long noted that they were poor cousins of the National Academy of Science and even though a few engineers were also members of the National Academy of Science, they felt their voice often was not heard and the National Academy of Science had become populated increasingly with basic scientists as opposed to applied science types. Augustus Kinzel who was with Union Carbide Corporation--now he had been a member of the Engineering Foundation for a long time, I think beginning about 1943, and about 1960, Kinzel was president of the Engineers Joint Council. The Engineers Joint Council was the primary voice of the engineers, but it had fourteen member societies, so to accomplish anything they had to get back to each of these societies and get everybody on board, et cetera. And so they concluded it wasn't adequate.

And a number of people, particularly in the Engineering Foundation, senior engineers, thought that some new accommodation was necessary. Now at that time, two other people whose paths I've crossed were Tony Gaudin from MIT who had been one of my major professors and had been involved with the Engineering Foundation since 1951, and in 1960 he was chairman of the Engineering Foundation so he was in a key position. Kinzel was on its board and Eric Walker, who was president of Penn State for many years, was also a board member and so the three of those people plus others got together and said what can we do about it? And so the Engineering Foundation acted as catalyst to study the formation of a National Academy of Engineering and this came to fruition in 1964. So in that four- or five-year period they were looking at the possibility of setting up a possible organization and so forth.

The Engineering Foundation then provided the seed money of $30,000. Now this was 1960, so again, $30,000 was a much more generous piece of change than it is today and they did two other things. As the National Academy of Engineering was being put together, its headquarters were at the Engineering Foundation in the United Engineering Center in New York City. After the things were up and going, why, it moved to the National Academy of Science building in Washington, but initially the headquarters were at the Engineering Foundation. In addition, starting in 1960, they detailed the Director of the Foundation, Harold Work, to help with all kinds of organizational details. He later became the first secretary of the National Academy of Engineering. So then Gaudin, Kinzel, and Walker all became one of the fifteen founding members of the National Academy of Engineering.

Swent: Do you have to get some sort of Congressional approval to be a national academy?

Aplan: Yes. The National Academy of Science was founded under Lincoln to give advice to the government on war, et cetera. And then in recent times two other organizations have split off. And they work cooperatively--their headquarters are in the same building, they have interlocking staffs and directorates and in goals--one is the National Academy of Engineering and the other one is the Institute of Medicine. So those three societies are the three principle groups and their main function is to give professional advice. Usually they have a lot of projects. Some of the projects are internally funded but the majority of the projects are in response to government requests.

Swent: Are they primarily with the executive or the legislative?

Aplan: Mostly with the executive branch of the government --in other words, the Secretary of Commerce will ask that they do a survey on such and such. The commissioner of the Federal Drug Administration will ask that they look into et cetera, et cetera. So it provides a sounding board. They also put together committees on many subjects and the committees are not exclusively members of those three societies--they will go outside and pick out members any place they want. I feel proud to have been elected a member in 1989, but before I was elected, I had served on several of the committees as an outside member. They go out and get expert advice wherever they can get it.

In summary, as far the Engineering Foundation is involved, if you look at the history of the Engineering Foundation in projects, in conferences, in founding things like the National Academy of Engineering, it has certainly accomplished a lot with a relatively small amount of money--the only monies they had was from their endowment, which for many years was just a few million. And so you take an interest of, say, 5 percent of that, and many years it was less than 5 percent, they didn't have all that much money, but if you look at all those conferences and everything else they've organized it's a tremendous accomplishment.

My twenty-five-year involvement with the Engineering Foundation began in 1966. At that time, now, mind you, the first conference was in 1962 and there had been only about twenty conferences up to 1966. In 1966, Professor Tom Meloy, who's now at the University of West Virginia, put together a particulate matter conference and I was vice chair. As for particles, all kinds of engineers run into particles--and the environmental and certainly the mineral engineers have to worry about particles, as do the chemical engineers--it goes on and on so almost everybody's involved. The conference was held in the summer of 1966 at Milwaukee.

Typically, the conference arrangement in those days was patterned after the Gordon Conferences that were held for the scientists such as for the American Chemical Society, and they would have a week-long conference in boys' schools, junior colleges, etc., where hey would live in the dorms and make use of the school facilities. They've changed that format some now; now they make arrangements mainly with hotels to get a cheap room rate and then they travel around the globe and have these conferences everywhere. Now the chair has to go out and get all the speakers--this is a week-long conference, so there are a lot of sessions and a lot of speakers and you have to go get them. And everybody has to

pay their own way. Okay? The so-called tuition or the fee is very minimal and the housing costs were minimal, but still, you have to encourage people to come to the meeting. And in my case, I had the arm put on me to help round up people to do this --to get speakers and so forth.

The following year, 1967, I became chair of the particle conference, which was also held in Milwaukee. I had a very interesting experience. We had a good program which was officially to start on Monday, but a number of people came in a day or so early. Well, we had a lot of foreign guests and as a help to a visiting friend, this was Professor Rumpf from Karlsruhe--Meloy, who had lived in the Milwaukee area--said well, I'll take you around town and show you. So in the evening he drove Professor Rumpf around town and showed him Milwaukee and so forth. At midnight, a race riot broke out down town.

Swent: Oh, my!

Aplan: And you may remember that riot of 1967. We lost a couple of speakers because they were in hotels downtown in Milwaukee and hadn't come out to the conference site yet and now they couldn't get out! So they stayed in the hotel [laughs] and hoped it would pass around them. It turned out to be a very successful conference however. At these Milwaukee conferences I first met Len Austin who later was to join our faculty here; at that time I was still at Union Carbide. Over the years I've probably participated in a dozen of these conferences as session chair, author, or in some way.

In 1975 and for several years thereafter, I was the AIME representative to the conference committee and the conference committee is the one that suggests possible conferences on such and such. So it requires an awful lot of ideas in order to put twenty-five conferences a year together, and you have to have to have about a two-year lead time so there are a lot of things in the works at any one time.

Swent: Twenty-five a year!

Aplan: Yes, so you can imagine what Sandy Cole did by providing the impetus to organize all this. Part time. Now, admittedly the main thing the foundation did in New York was act as a clearing house to print up the brochures and to handle the mailing lists and those things, but the chairs all had to do an awful lot of work. In 1976, at the recommendation of Paul Queneau—who was a vice president of Inco and had been on the E.F. board for the previous decade was retiring and he recommended that I be appointed as an AIME representative to the board. AIME agreed and I stayed on the board until 1990. I was chair in the period of 1985-87 and I was chair of the Seventy-fifth Anniversary Committee which was in the period of '88 to '90.

Also in 1989 as I retired from the organization, I felt quite honored that they put together the Frank F. Aplan Award, and I was the first recipient and it came to me out of the blue! I was told to come to this meeting and give a paper down in Florida. I went there and I didn't know a thing about it until one night they said stand up [laughs] and that's the first I knew of it.

Swent: How wonderful!

Aplan: I feel very honored to be counted among the AIME mining and metallurgical people who have served on the board and while this isn't an exhaustive list, just to give you an idea: Galen H. Clevenger, who was very important in cyanidation starting in the Black Hills about 1898 and later came up with the design equations for thickeners; J.V.N. Dorr, inventor of the rake classifier, agitator and thickener; Tony Gaudin, an outstanding professor who had been at Columbia, Utah, Montana Tech, and MIT; Augustus Kinzel who was vice president of Union Carbide; Paul Queneau who had been vice president of Inco; Dave Swan who had been a vice president both at Carbide and Kennecott; and currently "Som" Somasundaran, Henry Krumb Professor at Columbia, is the current AIME representative.

Swent: What a distinguished list of people!

Aplan: In 1991, a book was published called *The First Seventy-Five Years, A History of The Engineering Foundation,* which was authored by Lance Metz, a historian, and Ivan Viest, who is a civil engineer, and who had served on the board of the Engineering Foundation and was a member of the National Academy of Engineering.

In the last year there have been some substantial changes. There have been many new thrusts involved. The United Engineering Trustees have been dissolved and the building at 345 East 47th, which fronts the United Nations Plaza, has been sold to Donald Trump who's going to turn it into condos. It has a beautiful view of the waterfront, of the UN, etc., but the Engineering Foundation still survives. It's going to be called United Engineering Foundation. Same type of organization. The bulk of the proceeds from the sale of the building go to the five founder societies, but anyway the Foundation will get some money. And that's largely the end of the Engineering Foundation as I once knew it.

Swent: Did you have any relation to the Engineering Club?

Aplan: No. And then the old Mining Club--that wasn't a part of it either.

Swent: But was it sort of a social adjunct--did people go over there for lunch, or meet there?

Aplan: The only work it did, in a social way, was in the lower floors of the UET building--on the first floor and on the basement floor, were banquet facilities and meeting rooms so that the various engineering groups in the metropolitan area had a place to meet. When I worked at the Sterling Forest lab of Carbide in Tuxedo, the AIChE put together a night course on reactor design. I think we met one evening a month for four months and had lecturers to go over design of reactors--chemical reactors, not atomic-- we not only ate at the center, but we also used a conference room for that. The New York AIME group would meet there regularly, but in terms of an organized social activity like the Cornell Club or anything like this--it didn't happen.

American Institute of Mining, Metallurgical, and Petroleum Engineers

Aplan: Okay, the next section I would like to talk about is my involvement with professional societies. My lead society has always been AIME; I am a Legion of Honor member of both SME [Society of Mining engineers] and TMS [The Metallurgical Society]. To be a legion of honor member you have to be in for 50 years and I've made it for both of them, so I can say I belong to AIME for 100 years. [laughter] A little over because I achieved this last year in '97.

Both SME and TMS have changed their names to The Minerals, Metals, and Materials Society instead of The Metallurgical Society, and as you know, SME has changed from Society of Mining Engineers to Society of Mining, Metallurgy and Exploration.

Swent: Right.

Aplan: I have trouble keeping up with that.

Swent: But they keep the same initials.

Other Society Memberships

Aplan: I have belonged to the American Chemical Society for forty years; American Institute of Chemical Engineers for thirty years; I'm a life member of the American Society for Metals; I belong to Sigma Xi, the national research society, since my student days at MIT; I belong to the American Filtration Society, since its founding, I don't know, several years ago.

I belong to the Archeological Institute of America because of my interest in archeometallurgy; I first got interested in this by looking at the slags from some of the smelters in the Black Hills. I think a number of the reasons that some of the smelters didn't survive is the operators didn't really know much about smelting and if the slag gets too viscous, you have too high a drag-out of metal. When you melt the material, the heavy metal is supposed to settle at the bottom and the slag skimmed off, but if the slag is too viscous, not all the metal settles and so your recovery decreases--and particularly if you're dealing with precious metals, you don't want to lose any--

Swent: No.

Aplan: And then I belong to the Mining History Association--mainly through my interest in ghost mines.

Swent: Let's just add here that you have a whole wall in your office covered with citations and medals and awards--it's a very impressive list.

Aplan: Well, what you have to do is live long enough. If you live long enough and get this--

Swent: [laughs] Well, no, it takes more than that.

Aplan: If I had died from my first cancer at the age of fifty, I wouldn't have anything on the wall.

Swent: No; well, it's a very impressive list.

Aplan: The reason I have been involved with these things, and in so many different societies is because the mineral processing profession is so small that we have to draw information from all kinds of sources and so you have to be pretty well familiar with the literature and what's going in many disciplines. As I pointed out earlier, I started out in chem engineering but organic chemistry made a metallurgist out of me. I have used chemistry so often, in so many different ways, that I spend a lot of time in the chemical literature and so I want to know what's going on in that field and the same way with all these other fields. I was educated as a general metallurgist and so I've always kept an interest in physical metallurgy including alloy development, the properties of metals, et cetera, and so I get that both through TMS and the American Society for Metals, which is now called ASM International because they also are incorporating plastics and ceramics into their sphere of influence.

Professional Awards Won

Aplan: With regard to AIME meetings, mostly SME, but until a few years ago SME and TMS co-existed at national meetings--I've attended essentially all of the meetings since 1960 except for two years when I was hospitalized for cancer. SME has been my major society. That's where my major thrust lies--I was chairman of the Mineral Processing Division in 1972. I was made a Distinguished Member in 1978. I hold the Richards, Gaudin, and Taggart awards. The Richards is an AIME award, the other two are SME awards. These are three of the major awards given in the field of mineral processing, extractive metallurgy, from these societies. I've organized and chaired innumerable sessions, authored one book, and am currently organizing one session for the Advances in Flotation Symposium to be held in Denver this next February. That symposium, incidentally is in honor of Maurie [Maurice] Fuerstenau--so that's a nice recognition of his tremendous accomplishments over the years. One of the most important awards to me personally was to have been elected an honorary member of AIME. Now honorary membership is highly restricted. I think I was something like the 210th member since 1872, and so to join the ranks of Herbert Hoover and J.V.N. Dorr, D.C. Jackling, A.M. Gaudin and so forth, I felt quite honored

Also a few years ago I received the Mineral Education Award of AIME.

Because I'm retired and I have access to some secretarial facilities and I guess because I have done quite a bit of writing, I have, over the years, done a lot of work on putting together nominations of awards for other people. I've been involved in well over twenty of these things, just for AIME organizations. I think we've got an awful lot of good people out there and a lot of them haven't received proper recognition--particularly some of the plant operational people. It's very hard to detail what their contribution may have been because their contribution is mainly to get the job done. If you are a professor or maybe a chief engineer or a major engineer for a construction firm, you can easily say, He did this, but when you're an operator, you can't just say he did a good job, so that requires a lot of checking into the facts, to get input from other people, and then put this information together in a document and submit it to the proper committee. And as I've said I've been fairly successful in doing that.

Recently I've been nominating people for the National Mining Hall of Fame. Two of those that I did nominate and have been accepted are Robert H. Richards and Tony Gaudin. There are three others that I have kind of catalyzed, by having encouraged others to nominate, and at present, I have three nominations in the works. And you submit the nomination and hope your candidate makes it sooner or later. Included in the list that I have nominated but who have not yet been elected is Mrs. Robert H. Richards--Ellen H. Richards. She was the first female member of the Society of Mining Engineers I think about 1876. Now the AIME was only formed in 1872.

Swent: Oh, my.

Aplan: And she had a fantastic life. She accompanied her husband, Robert H. Richards, on his tours. At that time most of the copper came from Northern Michigan, the Upper Peninsula, and was owned by Boston interests, so Richards, who was professor at MIT, was used as the consultant for a lot of this and he took his wife along. She went along as chemist and she probably was the first one to set up an environmental base line. [laughs]

Swent: Well!

Aplan: For copper. She wrote a book on geology, she taught geology at MIT, and at Harvard, she started teaching in one of the local schools--probably Girls Latin in Boston, and ended up with a book. She then started using her science in other things and so she was probably the founding person of Home Economics and --

Swent: For heaven's sake!

Aplan: And there are three or four books available on her history now, one of them I think was published by the dietitians, one published by the Home Economics Society, and here is this one person that did all these things. And oh, she was also--

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Swent: You were just saying that you had nominated Mrs. Richards, and that she was the first woman member of the Society of Mining Engineers.

Aplan: Another thing that I do when I attend the AIME or TMS meetings, or anytime I'm in the West, I will take the official field trips. In the last five years I've gone to the Florida phosphate field, the Cripple Creek and Carlin gold operations, Leadville acid mine drainage plants, Grants uranium operations, San Manuel Arizona operations--and in addition, I will usually go to a meeting a few days early --I'll rent a car and I'll take my own field trip. And on that field trip I will sometimes visit current operations, such as Cripple Creek or Bagdad or Morenci--so wherever there's a meeting. When the meeting was at Phoenix I went to Morenci; the next time it was in Phoenix I went to Bagdad; etc. The official society trips are at the conclusion of the meeting and I'll take those, but my unofficial trips are usually at the beginning, so I will usually rent a car and I will arrive maybe on Thursday before the meeting, rent a car and take my own field trip. I will use a mixture of current operations and ghost mines. And to do this I have a big library of ghost mine books from every state in the West--well over a hundred of them, so I will plan out my itinerary ahead of time as to what I want to see. Usually it's about twice as much as I can accomplish so I might have to see other things: for example, I went to see the Anasazi ruins at Chaco Canyon in New Mexico in the Grants area and obviously I had to go to see Acoma [accent on second syllable] or Acoma [accent on first syllable]--I don't know how it's pronounced--

Swent: Acoma--accent on the first syllable.

Aplan: Acoma--the very famous Pueblo on a plateau. Anyway I take every opportunity I can. Oh, and I'll do other things also. I'll talk about this a little later--one of my hobbies are the narrow-gauge railroads and so one year when the meeting was in Denver I got there early and drove down to Durango and took the Durango-Silverton RR in the winter time. They don't run all the way to Silverton because of the snow slides just south of Silverton, but you can go quite a ways--including on the high line. On this little ledge, you can look down about 500 feet at the river. Anyway, I'll go do all these things.

Avocations: Mining History, Photography, Narrow-Gauge Railroads, Music

Aplan: Mining, as you can tell, is both my vocation and my avocation and I make use of these ghost mine books, but I also have several hundred history books on the West and extensive coverage on Black Hills, with well over 100 books and pamphlets on the Black Hills alone. The books I have mainly stressed are on the Black Hills and Colorado. With respect to the Black Hills I would take, sporadically, vacations somewhere--including often a couple of weeks in the Black Hills, but starting about 1970 I've gone out to the Black Hills almost every year. I rent a cabin usually up near Terry Peak and then start

visiting the ghost mines.

And with respect to that, I've had several very interesting experiences when I visited both ghost sites near Terry including the Mogul-Horseshoe Mill, where Clevenger was mill superintendent about 1905. This is on the northeast flank of Terry Peak and on another flank of Terry Peak was the old ghost town of Terry and this is where the Lundberg, Dorr & Wilson Mill was and where Dorr made those inventions, at about the same time. And a little later, actually Dorr and Clevenger both worked for the same company, the original Golden Reward Mining Company. I'm glad I visited those sites when I did because the site of the town of Terry has been obliterated. The site of Lundberg, Dorr and Wilson Mill has also been obliterated because that area has been mined by the present Golden Reward Mining Company which is a heap-leach operation. Searching for the Lundberg, Dorr & Wilson Mill site, it was easy enough to get up to the old town of Terry, and there were still a few old houses left, and all you could see readily was some of the tailings. The cities of Lead and Deadwood were using the tailings for various backfills and so forth, so if you had waited a few years the old tailings would probably have been gone.

But you couldn't see the site of the Lundberg, Dorr, & Wilson Mill which had been abandoned probably about 1915. The timber was so heavy that knowing where the tailings were--if you knew where the tailings were, you knew the mill had to be uphill somewhere, not far, but my oldest daughter and I spent the best part of an hour just finding the site. We looked all over and couldn't find it and we finally found it because I knew it was a custom mill and therefore it had to be close to the old railroad grade. And I followed the old narrow-gauge railroad grade, and I would keep looking down the hill all the time because in those days everything had to go by gravity and they had to build mills on the hillside so everything could flow by gravity down the hill and I finally found the site. There wasn't much left. There was a retaining wall; I tried to get a picture that was similar to the sketch that's in the forepiece of Dorr's book on cyanidation of gold and silveroOres, but couldn't do it; the trees were too dense. However, we found retaining walls and a few metal hoops that had held the vats, the leaching vats together, and my daughter found a bone ash cupel, and so I have a cupel from the Lundberg, Dorr, & Wilson Mill. [laughs]

Swent: Well!

Aplan: But it's interesting that this area had naturally revegetated, so in fifty years it had taken care of itself. You didn't' need to do any planting or anything else. And I think excepting in very high altitude and in arid areas, that they could do revegetation probably a lot cheaper than the way they're doing it right now. They're required to do something immediately, which is nice, but Mother Nature will take care of it. Not easily in deserts and not in high altitudes, but in a lot of other places it will take care of it quite naturally by itself.

I do a lot of picture taking.

Swent: You have some lovely ones in your office, too.

Aplan: When I was in Colorado in the fifties, I didn't have a camera and so I have a lot of pictures in my mind, but no record of them. So in more modern times when I've been out West, I always take pictures. I have at least 10,000 color slides and I will use these in various talks. I give talks to the local groups and I have also given talks elsewhere. When SME was at Salt Lake City a few years ago, I talked to their local industrial archeological society and showed them my pictures and so forth. And I also will print up several of my slides and use them as teaching aids in classes, such as my classic picture of an arastra which is a beautiful one from Buckskin Joe, Colorado, outside of Fairplay and Alma. Just to give you some idea, last year I spent a couple of weeks in Colorado in the Salida area and so I did Salida, Pitkin, Alpine Tunnel, St. Elmo--that area. And then I went down and spent a little over a week in the San Juans operating out of Ouray. You can get commercial jeep tours and some of them are just a mob scene--they'll load up an extended jeep with nine or ten people, but I was more fortunate; most of the tours I took were between one and three people in the jeep and that's nice because the driver will stop whereas if you had to drive the jeep yourself, you couldn't be doing much picture-taking.

Swent: Can't take your eyes off the trail.

Aplan: Also, on some of those jeep roads, no way would I drive anything. I think I would get out and walk and go back and tell the person I rented the jeep from, It's up there--[laughter] But I took about forty rolls of thirty-six exposure [laughs] so that's about 1500 pictures--now of course you often have to take several pictures of one thing to avoid problems with shadows, bright sunshine, focus, et cetera, et cetera.

I also have been very interested in narrow-gauge [railroads], particularly narrow gauges in Colorado, and when I'm doing trips I'll also visit places like the National Mining Hall of Fame, the Colorado Railroad Museum in Golden, the Black Hills Mining Museum in Lead, the Mining Museums in Colorado Springs and in Butte, and I contribute to all of those museums, which I think is important. They do an excellent job of preserving our past. In narrow-gauge I have again over 100 books. Most of them are about Colorado, but interestingly enough there's an operating narrow-gauge in the East and it's the East Broadtop which is only about an hour's drive south of us at Orbisonia, Pennsylvania. It was an old coal haul railroad and they still have a few miles of track. They have a lot of unused road bed and they have a Friends of the East Broadtop Society which has been fixing it up, however, that's expensive.

As you've probably noticed in my office, I have an extensive personal library on mining and mineral processing books. We have a very comprehensive library here that I can get to by walking three minutes from my office; it's just in the next building which is connected, but it's infuriating to go there and someone's got the book checked out for two weeks.

Swent: [laughs]

Aplan: Usually all I want to do is to check a reference and if I could look at the book for two minutes, I would have enough. Consequently, I have purchased all of the AIME transactions since they started the new format in 1948 and I have all of the mineral processing transactions going back into the 1920s. Then I've got most of the books that TMS and SME have published dealing with extractive metallurgy, hydrometallurgy and pyro, et cetera, and a few of those published by the Iron and Steel Society.

Swent: A lot of books!

Aplan: It is, but I feel it necessary. I also buy all of the AusIMM books I can get my hands on. They've done a fantastic job on some of the gold processing. Doug Halbe, when he worked out in Kalgoorlie, authored a couple of those gold volumes for AusIMM. And they have also had a wonderful two-volume set describing all of the processing operations in Australia. And before that they had a one-volume set, but anyway, I get these books because they're a tremendous learning experience. Also I have all the volumes of the Australian Coal Preparation Society and I've gone, I think, four times out to Australia, and when I go out there I make sure I see some mines. The last time I was out there I was at a meeting in Brisbane, and I arranged to go out to the Bowen Basin and see some of the coal prep plants. They had put in some column flotation and I'd seen those same plants as they were being built in the late seventies so it was interesting to see how the plants had evolved in that time period.

Another of my hobbies is World War II. When I was in the military they said go here and I went there and then they said go over here and I went over there and then they said go back here and I went there, and not much of it made any sense at that time and, of course, the military structure not only didn't inform you of what was going on, except to go forward, but much of the movement of the military was secret. And so you didn't know what was going on and of course not only did we not have any time, but we didn't get much information on what was going on out in the Pacific either. They had the Stars and Stripes [Army newspaper] but when you're in combat, you see the Stars and Stripes paper, shall I say infrequently, and I almost never saw a Yank magazine. I guess about the last time I saw a Yank magazine I was in England waiting to go to the Continent, and that came sporadically. So now I've gone out and bought books and I've got--maybe 300 or more, something like that, on World War II--all aspects of it and I quickly learned many of the things that I didn't know before.

For example, I spent a good deal of my time cursing the quartermasters who handled supply, because if you didn't have supplies on time, the most you could do was to yell at them. Of course they were all rear-echelon troops, so by definition they were worthless to a combat person, but as I got out of the military and got more involved in engineering, I began to see that it in reality it took a great deal of thought and planning--they didn't know when D-day was going to be--they didn't know how far they would be on D plus one month, three months, six months, one year--and yet they had to place orders for everything under the sun. Now, we had three and one half million people in Europe, so they had to place orders way ahead of time. There were no computers, and so it all had to be done by hand. The closest they had to mechanization were these file cards which they

punched out and then ran a rod through and lifted up the cards on the rod and that was about the extent of it. Recently there was a book on General Sommerall who was head of Army supply and it is fascinating to see what they did in order to accomplish what they did. But as I said, when you're on the other side, it looks differently. [laughter]

Swent: That's right.

Aplan: But anyway, you learn this from many of these books and from various unit histories and you learn why these things happened and what really was going on. Of course as I have said we knew nothing at the time--the only thing I knew about the Pacific was that the atom bomb probably saved my life, and that there was a battle at Guadalcanal and a few other islands. Even when you're training in the States, you're often out in the field in the rain and whatever, running around the swamps or running around the desert or running around someplace. You don't have any communication with anything and in infantry the principal thing you do is to put the left foot out front and now the right foot is the hind foot and that has to go out front, then the left one, et cetera and when you've gone on some of these long hikes or speed marches, you're just a machine; all you do is get that hind foot out, then get that other foot out. You don't have time to read anything; you don't have time to listen to a radio; I listened to very little radio in the entire time I was in the military. Often didn't have one, et cetera, so it's interesting to go back and find out what happened and why it happened.

I guess my other important hobby is big band and jazz music. And interestingly enough, I can't play a note on any instrument. It started roughly in 1949, when I became interested in big band and jazz records. I now have maybe 3,000 LPs and 2000 CDs, something like that. Now, as for the jazz music, my children all call it old fogey's jazz. I have a low tolerance for hippie music, though I do enjoy some folk and Country and Western music, but most of my jazz goes from early day New Orleans up through the fifties when we had cool jazz from the West Coast and then the Bird--Charlie Parker, probably the best alto saxophonist who ever lived.

The other thing that's kind of interesting is that presently there are a lot of re-creation bands--a lot of cities have part-time musicians that get together and play for fun, or sometimes they will play at an establishment. We have three or four of these groups in State College--Dixieland bands. One of them will play twice a month at one of the local pizza and then we also have a local big band. In State College we have not only a lot of musicians because there's a good music program in the high school, a strong music department on campus, and a local symphony and there's also a good string quartet, and a folk music group. I also have a lot of supporting books and discographies. My wife says, "What are you doing with all those books? I'm afraid the second story of the house will collapse from the weight!"

I guess my other major hobby is walking. I enjoy walking, always have.

Family Support Through Bouts of Cancer

Aplan: Let's shift gears and talk a little bit about personal things. As I've mentioned before I have three children: Susan the oldest daughter, who's a phys. ed. instructor, she has a B.S. from Penn State and an M.Ed. from a teachers college over in the eastern part of the state. My son Peter is an M.D. He got a B.S. degree here at Penn State and then went for his M.D. and the youngest daughter, Lucy, is in marine biology. My wife has an M.Ed. from U Mass, Boston and an M.S. in English from Penn State.

Through all this my wife has been a fantastic help. I've had two major cancers. In 1973 in December, I had noticed that my right hip looked a little bigger than the left one, but when you're fifty years old, you don't spend much time admiring your physique in the mirror and so I said, ah, I don't really believe it. But along about early December I got out the ladder and was cleaning leaves out of the gutter so they wouldn't freeze and to carry the ladder I used to throw my hip out and kind of balance the ladder --the middle rung--on my hip and Oh, it swelled up and hurt--oh! It went down a little bit but after a few days, I said I'm going to the doctor.

Our g.p. [general physician] was an excellent diagnostician, and he looked at it and said, I don't like the looks of this, and I asked him to give me his estimation of what it was --I said put it out on the line and he did. Then he said, "I'm arranging for you to have an x-ray right now."

Now this was Friday evening and it was probably 5:30 before he got the x-ray. And he called me at home and said, "I've arranged for you to see the orthopedic surgeon Monday."

Well, I went in to see the orthopedic surgeon Monday and the place was chaos. We only had about two or three surgeons in town, and one of the regular surgeons had just died of cancer and so the other surgeons had to take over all those other patients in addition to their own so there were people almost hanging on the chandeliers and my 2 o'clock appointment ended up at about 5:15. He took a look at it, looked at the x-rays and he had done his orthopedic residency at HUP--Hospital of the University of Pennsylvania in Philadelphia. So he got on the phone and he had me admitted within about five minutes and within ten minutes he had a surgeon. And he got a good one--because this doctor--Dr. Lane--later became chief of orthopedic surgery at Sloan-Kettering/Memorial in New York.

So I went down to Philadelphia, just after Christmas. I wanted to listen to the bowl games, [laughs] so I went down January 2nd and they operated on me in a few days. I went through every possible test--all kinds, a bone scan, where they inject you with technesium phosphate and then x-ray you and they found a large tumor growing on my hip but unfortunately it was growing among all the muscles going down the side of the leg.

So when the tumor came out, all those muscles came out. It was very difficult in those days to biopsy for a bony cancer. A fleshy cancer they could throw under the

microscope and get right away, but bony cancer was a big long-drawn-out deal. They had to make a thin section and diffuse out the calcium and so forth, so it would be maybe three days before you got the results, so it wasn't a case of starting to cut and say, well, we've cut enough. They said, "We may have to take the hip," and I said, "Well, if you have an option, try not to be that sure." Again, we've talked about engineers who have to deal with some degree of certitude--well, I said don't be quite that sure--if you can leave that hip and leg, do it. The night before my operation the doctor and the resident went up and practiced on a cadaver and because they did I'm able to walk. What they did was they took the gluteus maximus that goes down the backside and split it in two and threw it around and sutured part of it to the bone. It took me six months to learn to walk, but I now walk. And the reason I have a cane--I don't really need a cane to walk--I walk around the house all the time and I walk around a lot, and I can walk free for quite a distance, but if I have a cane, I can walk much faster and it is less fatiguing. Even though the bone structure for my hip to my foot still has integrity, because of those missing muscles, I walk with kind of a sideways wobble. The net result of the operation is my center of gravity has been moved to the right, so by carrying the cane on the left, I move my center of gravity back and I can walk much more smoothly and I can walk for miles. If I had to walk ten miles, I could do it.

Swent: Well!

Aplan: And I can walk as fast as I could ever walk. Now, the cane helps when I'm going uphill. If I'm just walking around, that cane is just used for touch and go, but if I'm walking up a hill and a fairly steep one, I come down on the cane quite vigorously and if I come to steps and there is no railing near by, I must rely on that cane. Anyway, it took me six months to learn to walk. You know, I did home exercises. There was no available physical therapist in State College so I stayed down in Pennsylvania for a couple of weeks going through extensive physical therapy and then the therapist gave me a series of exercises to take home. Later I would go back there every month, not only to see the doctor but to get another set of exercises, and I was eager to do exercises. I have quite a hole where they operated, about the size of a small football.

Swent: Oh, my!

Aplan: Then they chopped some bone off the other hip, about 2 by 6 inches or so and put it in the hole and wired it in there, so I will flunk almost always the airport security--not only do I have a lot of pens and pencils in my pocket and I usually have a brass belt buckle and change and even if I take all that stuff out, I will still often flunk because of that wire inside. [laughs]

Swent: As an engineer you must have been fascinated by the engineering of it.

Aplan: Oh, I was. I said then I went through the cane business and at that time I was head of metallurgy which was in the next building and it was on the second floor. They had an old elevator and if someone took the elevator up and didn't firmly close the door it often wouldn't close properly and I would come to the elevator and punch the button and

wouldn't get the elevator. And so I climbed two floors on canes a lot. Now coming down, that was kind of dangerous, but how are you going to get out of there, so sometimes you have to do those things. During this my family was very supportive.

Swent: I'm sure this must have been hard on them, too.

Aplan: My oldest daughter and son were in college. And they did a lot of driving me back and forth and my wife came down and lived at the hospital. They had a nice deal. They had a hotel, I think a Marriott, but something, just across the street from the hospital and connected by a second story bridge, so no matter what the weather, coming from the hotel, you could come right over.

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Aplan: Ten years later, in June of 1984, I woke up in the morning with a terrible ache in the lower part of my abdomen. Oh, it ached. I tried pain killer, and still I ached and ached, so when the hospital emergency room opened at six o'clock, I was there. They did tests for several days--everything going--before I got out of that hospital two months later I'd had something like seventeen physicians.

But anyway, they checked everything and they finally found leukemia, and it hadn't broken through to the blood yet, so they finally identified it by taking a bone marrow sample. I had acute adult mylogenous leukemia.

I spent the next two plus months in the hospital. They treated it by chemotherapy. They put in a catheter--came in the side--under the skin, and went up--they slit near your throat, pulled it through, under the skin, and then ran it down and hooked it into the heart. So I received all the nutrition and all the chemotherapy through that catheter.

Swent: Was that here?

Aplan: When we first came to State College there were very few physicians--the hospital was twelve miles away, most physicians had closed practice, and there were almost no specialists outside of a couple of surgeons and one eye specialist. You had to get out of here for everything else. The nearest major hospital was a little over an hour away. Hershey wasn't fully operational at the time so there was no hospital at Hershey to go to, either. There was a major hospital, Geisinger, in Danville, Pennsylvania, though I didn't use it. Shortly after the turn of the century a couple of doctors had worked at the Mayo Clinic and thought it would be a good thing to do for north central Pennsylvania. But starting fifteen years ago, a lot of physicians started moving into State College and State College started growing rather massively so by the time I got the second cancer we had two very good oncologists. They worked together in the same organization so actually you got two for the price of one.

The treatment at that time was such that they would lose about 30 percent of the people during the treatment because in the treatment, they had to destroy the blood, so you

have no white cells, so you have no immune system--you have no platelets, so you're a bleeder, you have no red cells so it's difficult to transfer energy. These strong drugs kill all the cells and so the bone marrow is not producing blood now, so I had something like twenty-five transfusions--in those days they knew about AIDS but there was no test for it in blood. I had to sweat out each one of those transfusions.

Swent: My!

Aplan: I had the option of going to Memorial in New York City--I'm glad I turned it down because that blood supply was totally polluted and if I had gone there I'm sure that I would have died of AIDS. But anyway, what they did is gave me the strong treatment, so they gave me big doses of the drugs which destroyed the blood. Because I was susceptible to every disease, I was isolated--I had no room-mate in the room. The only ones that I got to see were the physicians and the nurses on duty and they would only admit members of the immediate family.

Now as I went into the hospital, my daughter was scheduled to be married the next week, and I said, no matter what happens, go ahead. Go ahead. They had been a year in arranging that wedding and the business of getting the place for the dinner and all the rest of it--getting the cake, and the dresses and on and on and on. I'd gone through all of that and so I knew the problem--go ahead. They did this strong treatment and as a result, you're really in tough shape.

Swent: It must be awful.

Aplan: As I said, I had no immune system. As I was starting to get that treatment, I got pneumonia and almost went with pneumonia. Then I came back a little bit and they continued with the treatment. They took the blood down, essentially so they could identify no cancer with the microscope in the blood. They tapped me for blood twice a day to check it. And then I started to come back again, and after about a month I was back again. But during this first treatment, a fungus got loose in my body and invaded the sinus of my left eye. If you look at the picture of the eyeball, there are just very narrow nerve and blood vessels coming from the cranium into the eye socket--that fungus squeezed them and before they identified what the problem was, I had lost the sight of the eye. The eye still functions in all other ways, but I can't see anything. And then they were afraid the fungus would invade the other eye-socket or the brain cavity so they had to go in and operate, but they couldn't because I was a bleeder, so they fed me up on platelets for a few days and then went in and operated. They got the fungus out but they couldn't stop the bleeding. So they had to go in again and cauterize the whole thing.

Swent: Oh, my!

Aplan: Anyway it worked. Then I went through the treatment again after the blood came back, they took it down again, another strong treatment until the blood went kaput and I was susceptible to every disease known to mankind and then it came back. The second time it came back rather more slowly, so about late August--I had gone in maybe June 20th,

something like that. In late August they discharged me, but I had been in bed so long, that the muscles had atrophied and I had to learn to walk again. I came out of the hospital on a walker.

Swent: Oh, my!

Aplan: My daughter took a picture of me and I look like I'm about ninety years old.

Swent: I'll bet you felt it, too.

Aplan: Of course I had lost all my hair, but fortunately I had lost the side and not the top and then I lost the top and the side came back, so I wasn't completely bald any time. [laughs] When the hair came back in, it came back in curly. So I looked like a hippie with the nice curls all over my head in ringlets.

Swent: [laughs]

Aplan: When I got my first haircut, the curls never came back again. On top, the hair never came back so well, either. [laughter] Then they had a treatment called late intensification and seven months later I went in for this late intensification where I received the strong chemotherapy treatment again.

Swent: Oh, my!

Aplan: But at this time because they were losing so many during the treatment because in destroying the white cells you had no immune system—the oncologists came up with the concept of using a smaller dose each time but over a longer period of time.

So for seven months I went in one week a month, five days, morning and night, and got an out-patient shot of chemotherapy. Well, after about two days I was sick and I couldn't eat anything and I would vomit; my wife had to be very inventive. She would give me my favorite foods and my favorite vegetable then was broccoli; well, today I associate that with vomiting and that is no longer my favorite. And then my wife thought that it was probably partly psychological, which I'm sure it was, and so she just moved up the dinner time so we would have dinner at 3:30, four o'clock. And that cut down a lot of the vomiting.

Swent: Really. How very imaginative of her!

Aplan: Yes. But I still was nauseous all the time and the best thing that ever happened to me is I had a paper--two papers actually--scheduled for the International Mineral Processing Congress to be in Cannes, France the following June. They had thrown those papers back to me and they wanted changes made, and so I felt I had to do this at this time and so I stayed at home and wrote the revisions. It was the best therapy I ever had because if you just sit in a chair you begin thinking of immaterial stuff and you can't concentrate for a long period of time. If I started reading a newspaper, after about two paragraphs, my mind

would be chasing rabbits across the field or something and I couldn't concentrate. But I had to do those technical papers and so I could sit there for hours and concentrate and write and it was a tremendous therapy. So anyone who has to go through this--I should back up; one other helpful thing--my daughter who had just gotten married--they had postponed the honeymoon and she and my wife would come in and read to me--they first started just talking and then started reading and it turned out that the most useful books were the James Herriot books which I will kind of characterize as "All Things Wondrous Wise". That of course wasn't the title, but you know, "Bright and Beautiful, " et cetera. And we went through all those books. They are short stories.

Swent: They're very pleasant.

Aplan: They have a simple cast of characters. They are interesting, and you can stop anyplace and pick up the train of thought again--

Swent: That's right.

Aplan: So if I got fatigued, they would just stop and later start again. The other thing that helped was a little radio and earphone. The Olympics were on and so I would listen to the Olympics. And in those days they did a rather better job with the Olympics than they did later. I thought that the reporting of the winter Olympics in Japan was a catastrophe. Anyway, I had that to keep me busy. During the later seven months period I kept the catheter in but the catheter had to be kept clean so twice a day my wife had to put on a face mask, put disinfectant over where the catheter was on my side and on her hands, put on rubber gloves, and put some stuff into the catheter to make sure the blood didn't clot inside the catheter. So twice a day she had to do that, and that went on for seven months. So she's an angel in disguise, I'm telling you.

Swent: I'm sure.

Aplan: One other interesting experience I had: one night when I was in the hospital, I woke up and I felt some sticky stuff. Now they were feeding me sucrose, so I thought, gosh, that damned thing is broken, so I flipped on the light and I was bleeding. What had happened was the catheter was running backwards. And so I rang the nurse and she put in a stat call. They had a separate group called the I-V team but at night they would have only one on a floor. The stat call went in and I would guess within two or three minutes, I had two nurses in fixing that thing. So I was really impressed. We have a wonderful hospital here, and we've got some wonderful physicians in town. We are very fortunate.

Swent: Yes, you are.

Aplan: Then in the following March I went back to the university again. Now I had begun teaching for the spring term. I knew I was going into go to the hospital. I was teaching a course in flotation, and so for a course with two lectures and one lab a week I would do three lectures. Most courses were given Monday, Wednesday, and Friday, and since Monday and Wednesday and Friday periods were blocked off on their schedules, the

students were able to attend the lecture on Friday even though it wasn't scheduled. I was able to build up enough lectures to cover when I went into the hospital again supposedly for two weeks. They took the blood down and it started to come back again they discharged me but I picked up a bug, threw me back in the hospital and so I spent the whole month of March in the hospital. It was a good thing I had built up a lot of extra lectures in the flotation course. [laughs]

I really wasn't in good shape until May; the blood came back quite slowly. But I was operational; I was in the office every day, and just trying to go on about my business. Because if you just sat, it's bad. From this whole thing, I have concluded, that to survive cancer, you need early identification, a good family support system, a good attitude, a good doctor and hospital, and you should select your grandparents with care. [laughter] Those are the thing that you need.

I have tried to counsel others, because most people, when they get cancer, they think only of the worst. So I try to say, "Well, you know, it isn't always the worst thing. I'm probably the longest survivor of my form of leukemia in central Pennsylvania. Because at the time, I said they would lose 30 percent during treatment. They didn't tell me that if you were over sixty, they lost 50 percent. And I had just reached sixty. I was sixty the previous August, and this was June. And then if the treatment worked, at that time the mean life expectancy was one year."

Swent: Oh, my!

Aplan: Additionally they had very little data over five years. So my goal in life was to survive five years, and I've done a lot better than that. Fifteen.

Swent: I think you also have said that you never smoked.

Aplan: I didn't. I said, when I got pneumonia, if I had been a smoker--. One of the things that really helped me is my heart, lung, kidneys, and liver were all in good shape. And this worked out well because with this fungus, the only drug they had to counteract was awfully expensive and it affects the liver, so I ended up with jaundice out of this thing, too. They have since found out that the survivors all had to have this harsh treatment.

They essentially elected to give me both the harsh and the easy treatment, which was a wonderful thing. That was the best decision that I ever was the recipient of. Most of the people who just had the easy treatment, the same treatment but of lower doses didn't make it. My wife had to do all that stuff for a year, for which I am thankful.

And to anyone who has this problem and is in hospital for a long time and that has trouble with concentration, the James Herriot books. And so I have passed those books around to others who have had leukemia and it was of help.

Let me summarize --

Mild Student Protests at Penn State

Swent: I have a couple of questions too. You haven't said anything about the effect of the sixties, the student unrest, here at the campus. I think we should talk a little bit about that.

Aplan: There was very little at this campus. I'm only a block and a half from Old Main, and that's where the administrative center is. There were about 300 students who invaded that building, shouting and yelling and so forth--

Swent: When was that?

Aplan: In 1970? Somewhere between 1969 and 1972; I would guess '70. When about 300 students rioted, there were about 3,000 engineering and ag students who stood outside and said, "Get the hell out!" So the students in the technical disciplines didn't support that activity. The radicals also invaded the president's office and had all these demands. They brought in a few radicals from Pittsburgh and Philadelphia to help stir things up and they came in with these un-negotiable demands.

The president's house was on campus, just a block away from us, and they went through his house, broke into the house and bashed everything they could. As a consequence, the university has paid a fortune to get a presidential house off campus so the students cheated other students out of scholarship money and everything else.

When Eric Walker came here as professor of engineering, he had been at Harvard, working on torpedo research for the Navy, so they had a water tunnel, like an air tunnel, that did movement of objects through water. Of course it was supported by the Navy, so the object was largely torpedo research. Harvard wanted out of that business after the war, and so Eric Walker brought that Ordinance Research lab here and so now we've got the Garfield-Thomas Water Tunnel. Well, the students went over and chanted and yelled at that, and the main thing that came out of that activity was that they have changed the name to the Applied Research Laboratory. [laughs]

But there is so much money in a university that comes from the research -- and we had this tremendous expertise in flow of fluids and in acoustics and there were a lot of grad students who were doing research work over at the water tunnel, most of it the non-classified type. And in acoustics--we have an excellent acoustics group in the College of Engineering, and an excellent fluid flow group. So that the presence of that lab is very useful.

I saw one time on CBS this big riot at Penn State and while I was a little over a block from it, I didn't even know it was going on. So the bottom line is, the student riots were a big nothing here. The main thing they did is disrupt education and I think it encouraged President Walker to leave early, which is a shame, because he was a fantastic president for this university.

Swent: Of course you weren't teaching here then, but did they have anything like the loyalty oath?

Aplan: But I have been teaching here since 1968 and no loyalty oath. In central Pennsylvania, I don't think they had to have it! The fact is, when Nam started, several professors were saying, What can we do to help the military? It's quite a different attitude from that on the two coasts. Of course, it only takes a few students to rile up the whole system.

Swent: Do you have ROTC here?

Aplan: Yes, sure do. We have the biggest Naval RO in the country. And a big Air Force and a big Army RO. They are composed both of people who are on full scholarship and those who are doing it to get a small stipend for belonging. But it's a big program. And I didn't see the problems that they had on the West Coast at the University of Washington and the California schools where they wouldn't let the ROTC recruiters on campus and all the rest of the stuff. But I do think a lot of cadets kept a low profile. There weren't many of the RO students wearing their uniforms all over the place. But most of the protests were a big nothing. I think the reasons are, number one, we were in an isolated area,; and number two, this was mainly a technical school. we've got the biggest engineering school in the country, not counting the six engineering disciplines in this college, so we've got a big engineering operation; we've got a big ag college; so those people weren't interested in that kind of stuff.

Swent: No.

Aplan: They were too busy working; they didn't have time to do any rioting.

Mentors, Paying Forward; Aplan Scholarship for American Indians

Aplan: Let me summarize: my philosophy is that no man is an island. There are a half dozen or more people that have probably helped you along your career. Maybe some colleagues; there are usually several teachers in there, but a lot of people help you along the way, and I feel that I have been extra well blessed in that regard.

At the time my career was developing, I didn't think about it, but as I get older and thought about it a little more, and actually being a professor, where former students come back and thank you, you say, Gosh, you know--I was very fortunate--I previously told you that the person that really interested me in science starting at age ten was a house painter, Glenn Martin, in Ft. Pierre. After I had gotten my doctorate from MIT, he was living in Minneapolis and I sent him a thank-you note and I thank God I did as he died shortly thereafter. I didn't send many others though, and as you know, a lot of times the people you want to thank are dead and you can't do it. So I thanked your father through you. I feel bad now that I never thanked him during his life.

Swent: He was always very proud of your career. He thought a lot of you.

Aplan: But there were a lot of helpful people, and I feel I have been very blessed that people have helped me along the way, because you can't do it all by yourself, on your own. When you're a little boy from a small town on a small state, you're going to need a lot of help. As I said I have really been blessed--teachers and others--I had a tremendous sixth-grade teacher. I was doing nothing in school until I got this sixth-grade teacher, D.C. Mills, and then I started moving. It doesn't take much.

I guess my philosophy is that often you can't pay back, but you can pay forward. In other words, you might be able to write a letter to someone and say thank you, but you really can't do anything for them. Their own reputation and their own history of all they have been, has already been made and there's nothing you can do about that. But you can help someone else. At the funeral of a friend, quite a few years ago, one of his grad students got up and said, his philosophy was you can't pay back but you can pay forward, and I've tried to use that philosophy. I'll turn around a help someone else.

This is why I've gone out of my way to recommend all kinds of people for awards and honors and so forth, because we have so many good people in technology, all the way through, and particularly in this profession. I think there are just an awful lot of good people and many of them are unrecognized, so I try to do something about that. And I try and give generously to charity, particularly to the South Dakota School of Mines, and the Montana School of Mines. They're small schools. I also give to MIT and Penn State, but I give most to the first two because they are small schools, they don't have much money, they are in relatively poor states, and I think a little bit goes a long ways.

Among other things, I have established a scholarship at the South Dakota School of Mines for American Indians to come into metallurgy. Metallurgy has been a tremendous profession for me and I would like to let someone else have the same opportunity that I had. And let's face it, the Indians have been gypped, so if I can do some little thing to help, I'll do it.

Swent: You just received a very fine award from the School of Mines.

Aplan: Yes, I got the Guy March Award, a couple of years ago.

Swent: You got something else recently, didn't you?

Aplan: I got--they had a century 100 award in '84, and then I got the Guy March award last year. This spring I attended my fiftieth anniversary and then I have been elected to the South Dakota Hall of Fame in Chamberlain.

Basically, I'm proud of my family and I'm proud of my students. I've told you I don't have one weak student of all those I have had in grad school; not one weak one. And I hoped I have touched the lives of the several thousand students who have taken my course in Elements of Mineral Processing.

Swent: You must have been a wonderful teacher.

Aplan: Whether I was or not, I don't know, but I think I have helped because a number of them have come back and said I did something good.

Let me kind of summarize. I guess Im among the last of the mineral education generalists whose education covers the whole spectrum of geology, mining, mineral and metals processing, material science and product use. And because I have had a keen interest in the history of mining and metallurgy, I'm aware of what hasn't worked and what has worked and why. And I am very proud to have been in the mining profession. It has done well by me and I would recommend it to others.

Swent: Thank you very much for a fine interview.

Aplan: Let's wait and see how it comes out. [laughs]

Swent: This has been just wonderful and I thank you.

Transcribed by Amelia Archer and Eleanor Swent
Final Typed by Kathryn Stine and Eleanor Swent

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APPENDIX

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Lifelong Teacher & Researcher in the Mineral Industry

Dr. Frank Aplan

The year was 1933 when 10 year old Frank Aplan first became acquainted with Glen Martin, a house painter in Fort Pierre. This meeting was to spark Frank's lifelong interest in science. Glen was a bachelor, and not particularly well versed in the ways of children but he must have seen something in the young boy in front of him as he patiently and simply explained paint formulation. Glen had been a chemistry student at Iowa State early in the century, but had to quit school when his father died. He maintained his intense interest in chemistry over the years and had his own chemistry lab at home. Shortly after their first meeting, Frank received a Gilbert chemistry set for Christmas; and Glen served as Frank's consultant and mentor. They were to carry on extensive discussions on chemistry for the next decade.

Others in Fort Pierre also served to maintain his interest in science, such as druggist Guy Loupe; high school science teacher, Dorothy Gillespie; and school superintendent and math teacher, S. M. Stockdale. Classmate Bill Porter, who was interested in electricity, radio and telegraphy, also helped by sharing his knowledge of these fields.

All during the 30's, Frank dreamed of going to the nation's leading technical school, the Massachusetts Institute of Technology (MIT). However, the school's cost, high admission standards, and its location in far off Boston, made this an unattainable pipe dream. He never dreamed that two decades later he would receive a Doctor of Science degree in Metallurgy from MIT.

Not the least influence on Frank was his mother, Helen Fischer Aplan. Her husband had left and she had the job of raising Frank and his younger sister Carla and brother Jim. Hers was a tough job, especially during the depression; but she was always upbeat, supportive, enthusiastic and strongly encouraged reading, stick-to-itiveness and the value of education.

After high school graduation in 1941, Frank entered the South Dakota School of Mines and Technology in Rapid City. "Mines" was, and still is, a crown jewel for the State of South Dakota. Here, one could receive an economical, yet high-quality education. The school provided so many with that helping hand needed to succeed in a technical profession. He quickly found the college to be a challenging and stimulating place where good teaching abounded and everyone took great pride in the school. After taking a course in general metallurgy, taught by Professor Bancroft Gore, he decided that his life's work would be in Metallurgical Engineering. Two of Fort Pierre's successful metallurgical graduates from "Mines", Zay Jeffries and Donald Ricketts, would serve as role models. He was also energized by the geology courses he took from Professor Paul Gries, who, years later, is still inspiring students at "Mines."

On Nov. 2, 1942, Frank hitchhiked up to Fort Meade and enlisted in the Army. After finishing the school term he was sent to basic infantry training and later assigned to the 69th Infantry Division for further training. He went overseas with his division in November 1944 and served as a combat infantryman in Europe during World War II. He was dis-

charged in 1946 as a T/Sgt. Holding the Combat Infantryman's Badge, the Bronze Star Medal and a couple of battle stars.

He re-entered "Mines" that fall and after Professor Gore's death, he was stimulated by newly hired metallurgy Professor Jerry Van Duzee and Alex McHugh. Frank has long attested to the high quality education he received at South Dakota School of Mines & Technology.

In the summer of 1947 and 1948 Frank was hired by Homestake's Chief Metallurgist, Nathaniel Herz to work in the South Mill and Cyanide plants as a laborer and relief operator. This was an excellent learning experience since Mr. Herz and his assistants, Frank Howell and Claude Schmidt saw to it that he was moved around the entire milling operation.

For the balance of his professional career, Frank would alternate between academic life and work in industry. This would lead to a rather nomadic life but a fantastic learning experience. He has lived in places from Seattle to Boston, in 11 states and on foreign assignments. His activities included further education at Montana School of Mines (M.S., 1950) and MIT (Sc.D., 1957), university faculty positions at the University of Washington and at Penn State University and employment by five different corporations. In total, he has had 15 years of industrial experience in the mining, metallurgical and chemical industries, doing everything from plant operations through research and development. Further, he has had over 30 years of academic experience emphasizing both teaching and research.

The highlight of this era was his marriage in 1955 to Clare Marie Donaghue of Boston, MA. Today they have three grown children; Susan Bower a school physical education teacher and girls track coach, Peter Aplan, M.D., a pediatric oncologist and Lucy Aplan a marine scientist.

After a decade with Union Carbide, where he rose from research engineer to group manager of mineral engineering research and development, he strove to achieve family permanency by accepting an offer as professor and department head of Mineral Processing at The Pennsylvania State University, State College, PA. Since his arrival there in 1968, he has served at various times as department head, section chairman and distinguished professor. He is now Distinguished Professor Emeritus, and though retired, he still does some teaching, works with graduate students and authors technical papers.

Arrival at Penn State presented Frank with a wonderful opportunity to modernize the mineral-processing program. His prior academic and industrial experience had exposed him to the possibilities of new directions, as had consultations with friends in the academic community, such as Doug Fuerstenau (University of California, Berkley) whom he has known since his School of Mines days in 1946. Thus, Frank attracted new faculty, modified old courses and introduced new ones to broaden the curriculum and thus improve job opportunities for graduates from the program. He enthusiastically entered into undergraduate teaching and focused his research on the needs of industry and of society. Frank takes great pride in the nearly 50 graduate degree students trained under his direct supervision.

He emphasized environmental remediations by building on the past strengths of the existing academic program and an increased environmental emphasis in all courses. This was a logical extension of the program because the separation of metals and glass from municipal solid waste, the removal of acids and metals from water, and the trapping of fine particles from industrial off-gases, all require techniques that extractive metallurgical engineers have used long before environmentalism became popular.

In his spare time, Frank's vocation is also his avocation. He has an extensive collection of books on the history and the ghost mines of the West, emphasizing on Black Hills mining and metallurgical history. He has taken several thousand photographs of the ruins of these long abandoned operations and correlates these with a literature search of the same operations in their heyday.

He has received many professional honors, but he is proudest of his election to the National Academy of Engineering, the Guy E. March Medal of SDSM&T, and having an award named in his honor by The Engineering Foundation.

When asked his philosophy of life, Frank notes that a great many people help you along life's way. It is often not possible to pay back all of these people for their kindness, but you can pay forward for helping someone else.

Dr. Frank Aplan was nominated to the South Dakota Hall of Fame by his sister, Carla Sahr.

FRANK F. APLAN

Present Position: Distinguished Professor Emeritus of Metallurgy and Mineral Processing

Educational Background

B.S. in Metallurgical Engineering, South Dakota School of Mines and Technology, 1948
M.S. in Mineral Dressing Engineering, Montana School of Mines, 1950
Sc.D. in Mineral Engineering (Metallurgy), MIT, 1957
Minl. Eng. (honoris causa), Montana College of Mineral Science & Technology, 1968

Professional Experience

Academic

Assistant Professor of Mineral Engineering, University of Washington (Seattle), 1951-53
Professor and Head, Department of Mineral Preparation, Penn State University, 1968-71
Chairman, Mineral Processing Section, Penn State University, 1971-77
Chairman, Metallurgy Section, Penn State University, 1973-75
Professor of Metallurgy and Mineral Processing, Penn State University, 1973-90
Distinguished Professor of Metallurgy and Mineral Processing, Penn State University, 1990
Distinguished Professor Emeritus, 1992-

Industrial

1957-68	Research Engr. to Group Mgr., Mining and Metals Div., Union Carbide Corp. Tuxedo and Niagara Falls, NY
1957	Senior Scientist, Kennecott Copper Corporation, Salt Lake City, UT
1950-51, 1953	Mill Engr., Climax Molybdenum Co., Climax, CO
1949 (summer)	Engr. Asst., Day Mines Inc., Wallace, ID
1947-48 (summers)	Laborer, Relief Operator, Homestake Mining Company, Lead, SD

Memberships

American Chemical Society; American Filtration Society; American Institute of Chemical Engrs; American Institute of Mining, Metallurgical and Petroleum Engineers (Society of Mining Engineers and the Metallurgical Society); American Society for Metals; Archaeological Institute of America; Mining History Association; Sigma Xi; Engineering Foundation, Board of Directors, 1977-1990, Chairman of the Board, 1985-1987.

Honors and Awards

National Academy of Engineering, Elected, 1989
Honorary Member, American Institute of Mining, Metallurgical and Petroleum Engineers (AIME), 1992
Legion of Honor, AIME, 1997
Mineral Industry Education Award, AIME, 1992
Distinguished Professor, Penn State University, 1990
Engineering Foundation Award for Mineral Processing (Frank F. Aplan Award), 1989
Robert H. Richards Award, AIME, 1978 (highest professional award in Mineral Processing)
Percy Nicholls Award, Joint AIME-American Society of Mechanical Engineers Award, 1997
A.M. Gaudin Award, Society of Mining Engineers, 1992
Arthur F. Taggart Award, Society of Mining Engineers, 1985
Distinguished Member, Society of Mining Engineers, 1978
Honorary Degree, Mineral Engineer, Montana College of Mineral Science and Technology, 1968
Centennial 100 Alumni Award, South Dakota School of Mines and Technology, 1985
Guy E. March Outstanding Alumnus Award, South Dakota School of Mines and Technology, 1996
Distinguished Alumnus, South Dakota School of Mines and Technology, 1999
Distinguished Alumnus, Montana Tech, University of Montana, 1999
South Dakota Hall of Fame, inductee, 1998
Matthew and Anne C. Wilson Teaching Award, Penn State University, 1977
Best Presentation Award, Society of Mining Engineers, 1972
Bronze Star Medal, Combat Infantryman's Badge, U.S. Army, World War II, Europe, Infantry

Academic Research

Supervisor of 50 M.S. or Ph.D. candidates, approximately half of coal preparation (including 17 in coal flotation) and half in ore processing. Author of over 150 technical publications.

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F. F. Aplan

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17. "Evaluation to Indicate Processing Approach," F.F. Aplan, Section 27.3 in SME Mining Engineering Handbook, ed. by A.B. Cummins and I.A. Given, New York: AIME, pp. 27-15 to 27-18, 27-86 to 27-88, 1973.

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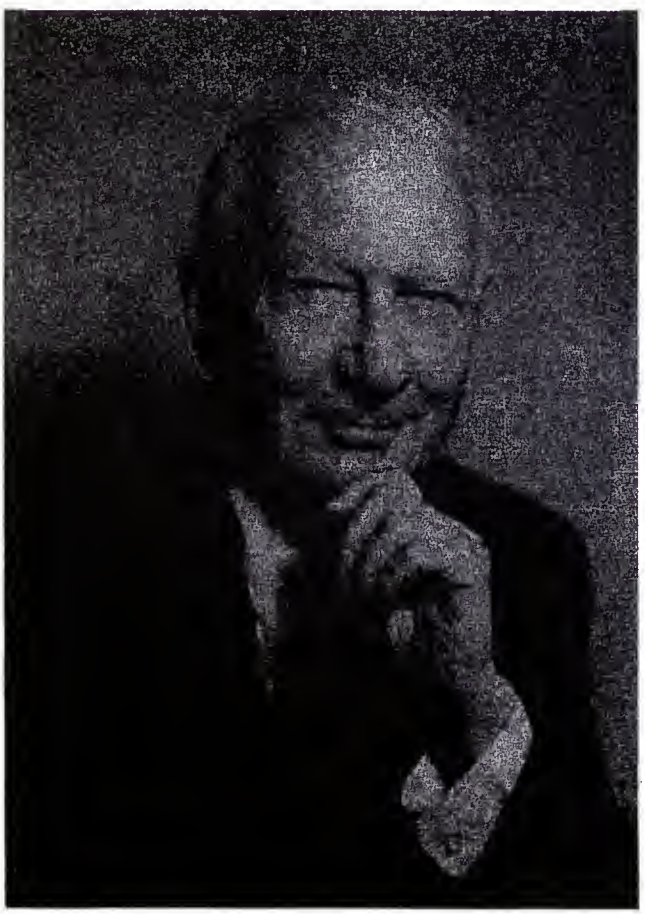

Fig. 1 — Antoine Marc Gaudin, 1900-1974 (Photo courtesy of H.R. Spedden).

F.F. Aplan

Prologue

Antoine Marc Gaudin (Fig. 1) was truly a giant in the field of mineral processing, and his shadow is still cast long on our profession. "Tony," as his students affectionately called him (but never to his face), came to the United States in 1917 and enrolled at Columbia University where he studied under Professor Arthur F. Taggart. Later, as a lecturer, he wrote his classic comminution paper (Gaudin, 1926). This important work led to his appointment as an associate professor at The University of Utah, where he conducted highly original work on flotation fundamentals that is still widely quoted today (Gaudin et al., 1928-30).

In 1929, he was appointed Research Professor of Ore Dressing at the Montana School of Mines in Butte. Shortly thereafter he published his first book, *Flotation* (Gaudin, 1932). Because Gaudin could so quickly cut through the fog to get to the essence of a problem, this is still a valuable reference book. It is a valued part of my personal library, and I consult it frequently.

Over the next decade, he conducted an outstanding graduate research program at Butte, but, more importantly, he honed his undergraduate lectures and produced the century's outstanding text in the field, *Elements of Mineral Dressing* (Gaudin, 1939). More than 50 years later, this terse book is still found to contain most of the elements of the discipline. Its sections on the

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movement of solids in fluids, gravity concentration, flocculation and flotation clearly anticipated the future.

In 1939, Gaudin was appointed Richards Professor of Mineral Engineering at MIT, where he proceeded to revolutionize teaching and research in the field. By the time I had arrived in 1953, he had attracted a large group of graduate students and several energetic and farseeing faculty members (Charles, deBruyn, Fuerstenau, Schuhmann and Spedden).

Up until the late 1960s, MIT gave perhaps 90% of all of the doctorates in the mineral processing field. These students have since spread the "gospel" far and wide. It is my pleasure to have been one of those graduate students and to now join the select group of six of his former students (plus two of the students of one of these students) who have won the A.M. Gaudin Award. The love and respect his former students had for him is exemplified by the annual "Breakfast with Antoine," held at the annual AIME meetings from 1961 until his death. Rush Spedden (1976) has presented a much more detailed biography of him.

My interest in coal began at an early age when my father was a fire marshal, for the state of South Dakota, with responsibility for the lignite coal mines. Later I learned about coal preparation at the South Dakota School of Mines and Technology. I also obtained research experience with coals at the Montana School of Mines (under Professor D.W. McGlashan who had done graduate work in coal preparation at Penn State), with Gaudin at MIT and in industry.

My best experience with coal, however, came as a young assistant professor at the University of Washington, where I had the wonderful opportunity to learn from the US Bureau of Mines' outstanding experts in coal preparation, H.F. Yancey and M.R. Geer. Years later, when offered a professorship at Penn State, I jumped at the opportunity to begin a major program in coal preparation and in coal flotation.

Introduction

It is impossible to repeat loudly or long enough Luckie's (1988) statement regarding the broad range of coals and their highly variable chemical and physical properties: "There is no such thing as coal; there are coals." Very fortunately, the ASTM (D-388) classification system, as well as classification systems of foreign origin (Hower and Parekh, 1991; Osborne, 1988), prove that it is possible to codify this seeming chaos.

In reviewing the literature of coal flotation, one is struck with the fact that there is often insufficient information to generalize the results. Frequently, the following may be poor:

- the characterization of the coal as to its source and chemical and physical properties;
- the description of the relevant laboratory or plant operating procedures;
- the knowledge of the applicable literature; or
- the conclusions regarding the work and its integration with the research of others.

Since coal is so highly variable, laboratory or plant data are often worthless unless the reader is given some frame of reference as to the nature of the coal used. With such information, the results can be generalized. The coal source and its important rank parameters, together with a grasp of the relevant coal preparation and use information, are needed to understand the value of a given literature source.

The early portions of this paper rely heavily on the work of others, while the latter portions are largely a summary of the research work of the author and his associates. It is not to be considered as a general review of the field of coal flotation.

US coal fields and sulfur reduction potential

This subject is of particular importance in setting the stage for what will follow. In today's environment, a major goal of coal preparation and coal flotation is to reduce the sulfur and ash contents, especially the former, of the raw coal.

The US is blessed with an abundance of coal reserves, nearly 460 Gt (500 billion st), enough to last the nation for centuries. For convenience, the major coal fields in the continental US may be divided as follows:

- Anthracite (<0.7% S), located mostly in Pennsylvania;
- Southern Appalachia (<1% S), in Alabama, eastern Kentucky and Tennessee, western Virginia and southern West Virginia;
- Northern Appalachia (~3% S), in Ohio, Pennsylvania and northern West Virginia;
- Eastern Midwest (~4% S), in Illinois, Indiana and western Kentucky;
- Western Midwest (~5% S), in Iowa, Kansas, Missouri and Oklahoma (also includes Texas lignite at ~1% S); and
- Western coals including:
  - bituminous (<1% S), located in many western states;
  - subbituminous (<0.5% S), in Montana and Wyoming; and
  - lignite (<0.5% S), in North Dakota, Montana and South Dakota.

In a classic work by Cavallaro et al. (1990-91), the authors characterized the ability of almost 1000 US coals to meet the 1.2 lb SO_2/million BTU sulfur standard. For the Anthracite, Southern Appalachia and Western US coal fields, many of the raw coals meet this sulfur specification, while most of the rest will qualify by using elementary crushing and preparation. Although few of the Northern Appalachian raw coals will meet this standard, about one third of them will qualify if crushed and cleaned. These coals offer an especially attractive target for coal preparation engineers.

The two Midwest coal fields pose the most serious problem in sulfur reduction. Essentially none of these raw coals or those cleaned by gravity methods will meet the specification. The basic problem is that many of these coals contain large amounts of organic sulfur (1-2%) that cannot be removed by cleaning. Based on their organic sulfur content alone, most of these coals will fail to meet the current sulfur emission standards.

For the past two decades, coal preparation engineers have mostly focused on sulfur reduction. However, the use of flotation and gravity concentration methods also performs another valuable function. By eliminating the ash-forming minerals, these methods minimize transportation and grinding costs as well as boiler slagging and erosion.

Coal genesis

Coal is a combustible mineral substance resulting from the degradation and alteration of vegetable matter, largely in the absence of air. Coals in the continental United States represent two drastically different coalification periods. In the eastern half of the US, the coals are of Pennsylvanian or Permian age, while those in the West are Cretaceous and Tertiary in age. This difference in genesis (Table 1, Arnold and Aplan, 1989) can sometimes result in rather different properties for coals seemingly of the same rank. High-rank Western coals (such as

Table 1 — Genesis of continental US coals (modified after Arnold and Aplan, 1989).

Process	Eastern US	Western US
Coalification:		
Age	Carboniferous ~300 Ma	Cretaceous, Tertiary ~25-100 Ma
Temperature	Normal geothermal gradient ~30-40° C/km	Elevated temperatures - higher gradient - igneous intrusions
Pressure	Deeply buried - greater compaction - less porosity - greater anisotropy for a given rank	Not deeply buried - less compaction - greater porosity - less anisotropy for a given rank
Chemical factors:		
Plant precursors	Giant trees, ferns	Conifers, flowering plants, resinite (may be intimately associated with vitrinite)
Hydroxyl content	Lower OH for a given rank	Higher OH for a given rank

medium volatile bituminous) may have been coalified in one-tenth the time of their Eastern analogs. Consequently, coal property differences due to source should not be unexpected.

Raw coal properties

Coal properties

A terse correlation of the chemical and physical properties of coals with ASTM rank has been developed by Given (1984; see also Aplan, 1976). His basic tabulation has been modified and expanded by the author (Table 2). The values for % volatile matter, %C and %O have been adjusted to reflect the analyses of nearly 600 coals in the Penn State Coal Data Bank. To the original table by Given have been added the % equilibrium moisture (Davis and Glick, 1988); relative hydrophobicity (Arnold and Aplan, 1989); pH for point of zero charge in water (Onlin, 1984; Aplan, 1988); surface area (Gan Nandi and Walker, 1971); Hardgrove grindability and % friability (Hower and Parekh, 1991).

From Table 2, a regular progression in the various chemical and physical properties of coals is seen to proceed from the rank classification. Thus, any one of several rank parameters will provide a general guide to many properties of a particular coal. To fix the properties more specifically, however, often several parameters may be necessary.

As mentioned previously, a given coal's source location is important. Not only does the genesis provide useful information, inferences can be made from other coals at nearby locations. For example, the hydrophobicity of a given coal from the Western United States will deviate more from the norm than will its Eastern cousin. Further, the presence of even a small amount of the very highly hydrophobic resinite in Western coals may mask a sample's true hydrophobicity. In addition, the analysis may differ slightly from the average of that rank. Eastern mvb coals typically show 86-92% C (DMMF), while some Utah mvb coals may contain only 81% C. Further details on the properties of coal are given elsewhere in the literature (Elliott, 1981; Lowry, 1963; Van Krevelen, 1961).

Moisture: As reported in Table 2, the equilibrium (inherent) moisture in a coal is that determined at 96-97% relative humidity and 30° C (86° F) (ASTM D1412). The average value given for each rank is based on data from the Penn State Coal Data Bank. This equilibrium moisture value differs from the total moisture in a coal, which is determined from proximate analysis by drying at 107° C (225° F) ± 3° (ASTM 3302). For high-rank coals, the

Table 2 — Approximate values of some coal properties in different rank ranges (dry, mineral-matter-free basis)*.

ASTM rank	Lignite	Subbituminous	High volatile bituminous C	B	A	Medium vol. bituminous	Low vol. bituminous	Anthracite
Rank abbreviation	**llg**	**sub A,B,C**	**hvCb**	**hvBb**	**hvAb**	**mvb**	**lvb**	**an**
Equilibrium moisture, avg., %	35	16–29	12	7	4	3	3	5.5
Volatile matter, %	33–62	60	34–52	36–50	31–50	20–31	10–20	<10
Calorific value, DMMF, BTU/lb	7,000	10,000	12,000	13,500	14,500	15,000	15,800	15,200
Calorific value, DMMF, kj/kg	16,000	23,000	28,000	31,500	34,000	35,000	37,000	35,000
%C, average	73	76	80	82	85	89	91	95.5
%C, range	66–76	71–81	76–84	79–85	83–89	86–92	87–92	92–97
%H	4.5	5	5.5	5.5	5.5	4.5	3.5	2.5
%O	25–16	25–11	18–8	13–7	13–4	4–3	3	2
%O as OH	11–7	9–5	9–4	6–3	6–2	3–1	3–1	1–0
%O as COOH	10–6	9–4	low	tr-?	0	0	0	0
Aromatic C atoms % of total C	50	65	?	?	75	80–85	85–90	90–95
Average number of benzene rings/layer	1–2	?	2–3	2–3	2–3	2–3	5?	>25?
Reflectance, %, vitrinite	0.2–0.3	0.3–0.4	0.5	0.6	0.6–1.0	1.4	1.8	4
Plasticity and coke formation	no	no	yes	yes	yes	yes	yes	no
Hydrophobicity	←decreases	←decreases	←decreases	←decreases	←|←	maximum	→|→	decreases
Point of zero charge (PZC) pH	2	2	|←decreases	←decreases	←decreases|	7–8	7–8	variable
Density (He), vitrinite	←increases	←increases	←increases	←increases	minimum		greatly increases	→
Surface area (CO_2) m^2/g	250	100–300	100–220	100–220	100–220	200–250	200–250	200–400
Hardgrove grindability	35–50	40–55	45–80	45–80	45–80	70–115	70–115	25–50
Friability, avg., %	12	20–30	43	43	43	70	70	33

*Modified and expanded from the original tabulation of Given (1984).

two values may be similar. However, for low-rank coals, great differences between equilibrium and total moisture values are common.

Another moisture value frequently encountered is the free or surface moisture. It represents that moisture removable by mechanical means. For an hvAb coal, the surface moisture of +25-mm (1-in.) particles is only 1 or 2%. For –1.2-mm (–14-mesh**) fines, however, 25-30% moisture is not uncommon.

Density: Table 2 indicates that vitrinite density passes through a minimum. At 70% C, vitrinite density is ~1.45 g/cm^3 (90.6 lb/ft^3). It decreases to a minimum of ~1.25 g/cm^3 (78.1 lb/ft^3) at 84-88% C, before rising sharply to ~1.80 g/cm^3 (112.5 lb/ft^3) at 97% C. For vitrinites of the same carbon content, the densities of exinites are lower and those of micrinites and, especially, fusinites are higher (Aplan, 1988; Van Krevelen, 1961).

Forms of oxygen: Considerable controversy exists regarding the forms of oxygen in coal and the means of analyzing for them (Dryden, 1963; Van Krevelen, 1961). The values in Table 2 for carboxyl (COOH) and hydroxyl (OH, both phenol and alcohol) come from the Penn State Coal Data Bank and a variety of other sources (Blom et al., 1957; Dryden, 1963; Fuerstenau et al., 1983; Van Krevelen, 1961; Yarzeb et al., 1979). In their paper, Yarzeb et al. give the OH content of a large number of US coals and a regression equation as a function of the %C in the coal.

One of the most detailed studies of oxygen functional groups in coal is that of Blom et al. (1957; Van Krevelen, 1961). As shown in Table 3, the oxygen functionalities also include ether (C–O–C), ketone (C=O) and methoxy (OCH_3) groups, in addition to OH and COOH. These data are in general agreement with those of Table 2, although the 65% C coal is a European brown coal not listed in Table 2.

As the total oxygen and oxygen functional groups increase, the bituminous coal surface becomes progressively more polar. Its hydrophobicity, floatability and PZC in water all decrease.

Coal hydrophobicity: Of the several means for determining coal hydrophobicity (Aplan and Arnold, 1991), methods based on the contact angle are most commonly used (Parekh and Aplan, 1978; Gutierrez et al., 1984). These include the captive bubble (a bubble deposited on a polished surface of coal immersed in water or a solution) and the sessile drop (a drop of liquid placed on the polished surface) methods. Figure 2 (based on the composite data of Arnold and Aplan, 1989; Gutierrez et al., 1984; Horsley and Smith, 1961; Onlin and Aplan, 1989) shows that hydrophobicity is correlated with %C.

Note that the captive bubble and the sessile drop methods give different values for the contact angle. Gutierrez et al. (1984) believe that the coal surface is a mosaic of hydrophilic and strongly and weakly hydrophobic sites. The captive bubble measures only the strongly hydrophobic sites, while the sessile drop measures the total (strong plus weak) hydrophobic sites.

In addition, the sessile drop method shows a much greater data scatter, although the measured maximum hydrophobicity

Table 3 — Approximate content of various oxygen functional groups in coal (based on the data of Blom, Edelhausen and Van Krevelen, 1957).

%C	Total O	C–O–C & other	OH	C=O	COOH	OCH_3
95	1	1	—	—	—	—
85	6	2	3	2	—	—
75	16	6	7	1	1	—
65*	28	10	7	2	8	1

*A European brown coal.

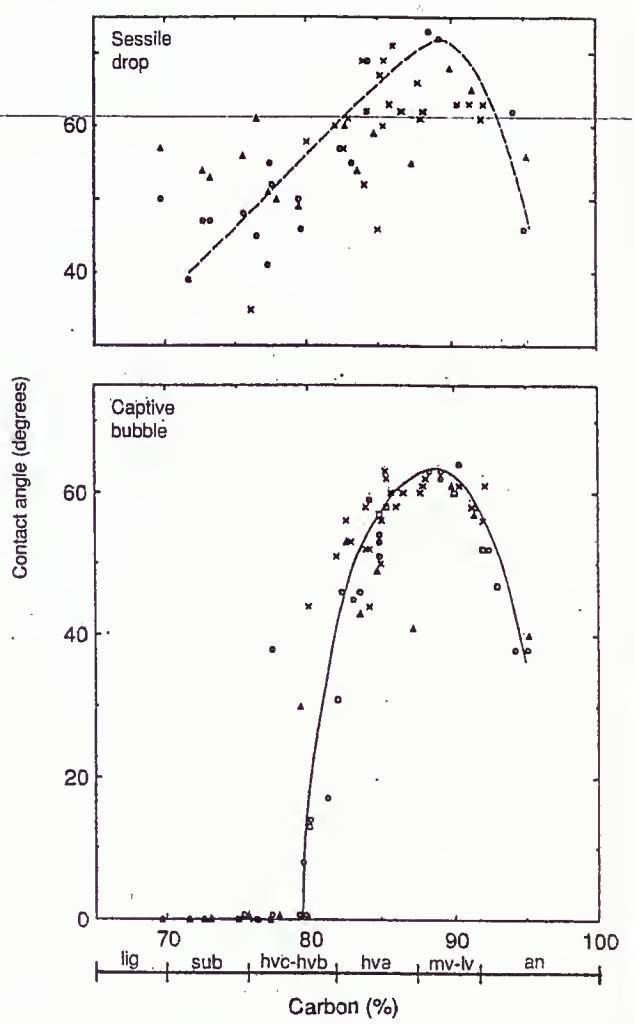


Fig. 2 — Contact angle as a measure of the hydrophobicity of vario coals (most US) as a function of %C. ✖ = Arnold and Aplan (198 O = Gutierrez, Purcell and Aplan; □ = Horsley and Smith (195 English Coals; △ = Onlin and Aplan (1989).

occurs at ~88% C ± 2% in both cases. Similar correlations c be obtained using fixed carbon (maximum ~80% FC), oxyg (maximum 3% O) or OH (maximum ~2.5% OH). It has be found that the contact angle data scatter is greater for Weste than for Eastern US coals (Arnold and Aplan, 1989). Maximu hydrophobicity also occurs at a mean maximum vitrinite refle tance of 0.9-1.6%, and the best correlation, using either t captive bubble or the sessile drop method, is with this vitrini reflectance (Arnold and Aplan, 1989).

It should be noted that all of the contact angle data report above were obtained using only the bright (vitrinite-rich) fra tion of the coals. In this way, the influence of other macera locked particles and the high-ash-content portions of the r coal can be avoided. Such an approach is realistic, since the Pe State Coal Data Bank shows that for 520 coal samples, 83.4% the maceral content is vitrinite (or huminite in low-rank coal.

As might be expected, coal macerals show a wide variati in their hydrophobicity. Arnold and Aplan (1989) found t following:

- The hydrophobicity of the principal coal maceral (vitrini is a function of such rank parameters as the ASTM ra

**Tyler standard sieves have been used in this paper.

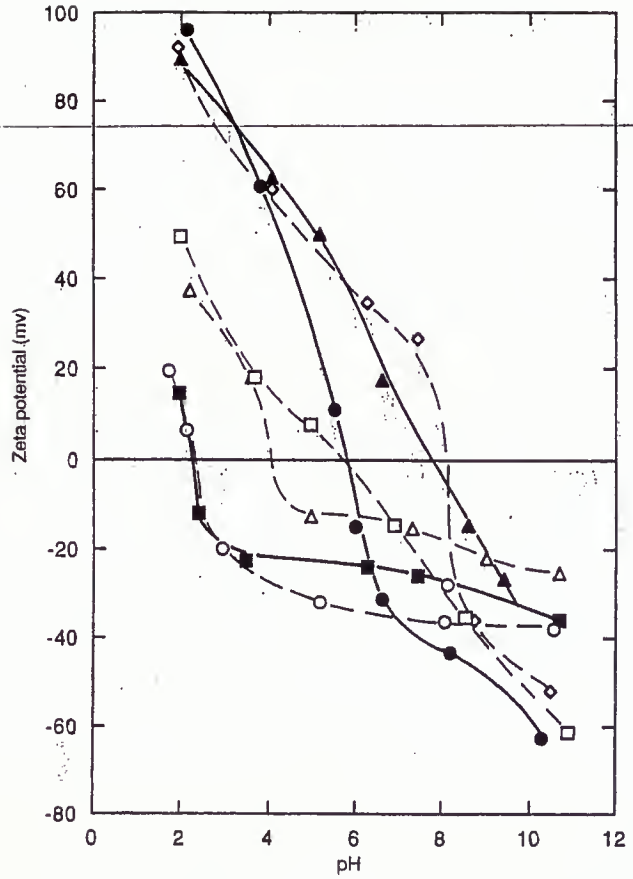


Fig. 3 — Zeta potential and point-of-zero charge of coals of various ranks as a function of pH (Onlin, 1984). ◇ lvb, ▲ mvb, ● hvAb, △ hvBb, □ hvCb, ■ sub, ○ lig.

%FC, %C, %O, %OH and vitrinite reflectance (Fig. 2).

- Vitrinite is more hydrophobic than fusinite from the same source.
- Pseudovitrinite is slightly more hydrophobic than vitrinite from the same source.
- Exinites are typically the most hydrophobic of the coal macerals:
  - Western resinite (Upper Cretaceous; Utah) is very hydrophobic, about as hydrophobic as paraffin wax.
  - Sporinite (Indiana) and zukerite (Utah) are also strongly hydrophobic but less so than the Western resinite.
  - Natural bitumen (Pennsylvania) and oil shale bitumen (Zebula et al., 1987) show hydrophobicities similar to that of high-rank vitrinite.
  - Eastern resinite (Carboniferous; Kentucky) is only slightly hydrophobic (Hirt and Aplan, 1991)

The influence of the source and genesis factors given in Table 1 leads to some variation in the hydrophobicity of Western and Eastern coals as a function of rank parameters. Also, the striking difference in the hydrophobicity of Western and Eastern resinites results from their very different geneses.

Zeta potential of coal: As shown in Fig. 3, the effect of changing coal rank is to lower the point of zero charge (PZC) from pH 7-8 for high-rank (lvb, mvb) coals to pH ~2 for low-rank (sub, lig) coals, with the intermediate ranks falling in between (Aplan, 1988; Onlin, 1984; Onlin and Aplan, 1989). Wen and Sun (1981) have demonstrated that continued oxidation of a high-rank coal produces a similar lowering of the PZC. Thus, oxidation of a coal makes it act like a coal of lower rank.

Further details on the properties of coal are given elsewhere (Elliott, 1981; Lowry, 1963; Van Krevelen, 1961), as is their relevance to coal preparation (Aplan, 1988; Leonard and Hardinge, 1991).

Properties of the pyrite and ash-forming minerals

In considering a flotation process, it is important to know the properties of the mineral to be floated (in this case, coal) and the minerals not to be floated (pyrite and the ash-forming minerals).

Pyrite: There are three forms of sulfur in coal: sulfatic, organic and pyritic. The sulfate sulfur is usually negligible (~0.02% S), except where gypsum is present or the coal-source pyrite has been oxidized. The organic sulfur is inherent to the coal structure and cannot be removed by physical means. This leaves only the pyritic (or marcasitic) sulfur that can be reduced by preparation means. However, if the pyrite is finely disseminated, locking may seriously restrict its removal. Research at the US Bureau of Mines (USBM) has demonstrated that the pyritic sulfur removable by physical means (gravity) is a linear function of the log mean size of the pyrite grains (McCartney et al., 1969). Therefore, a crude estimation of its liberation potential can be made from microscopic data.

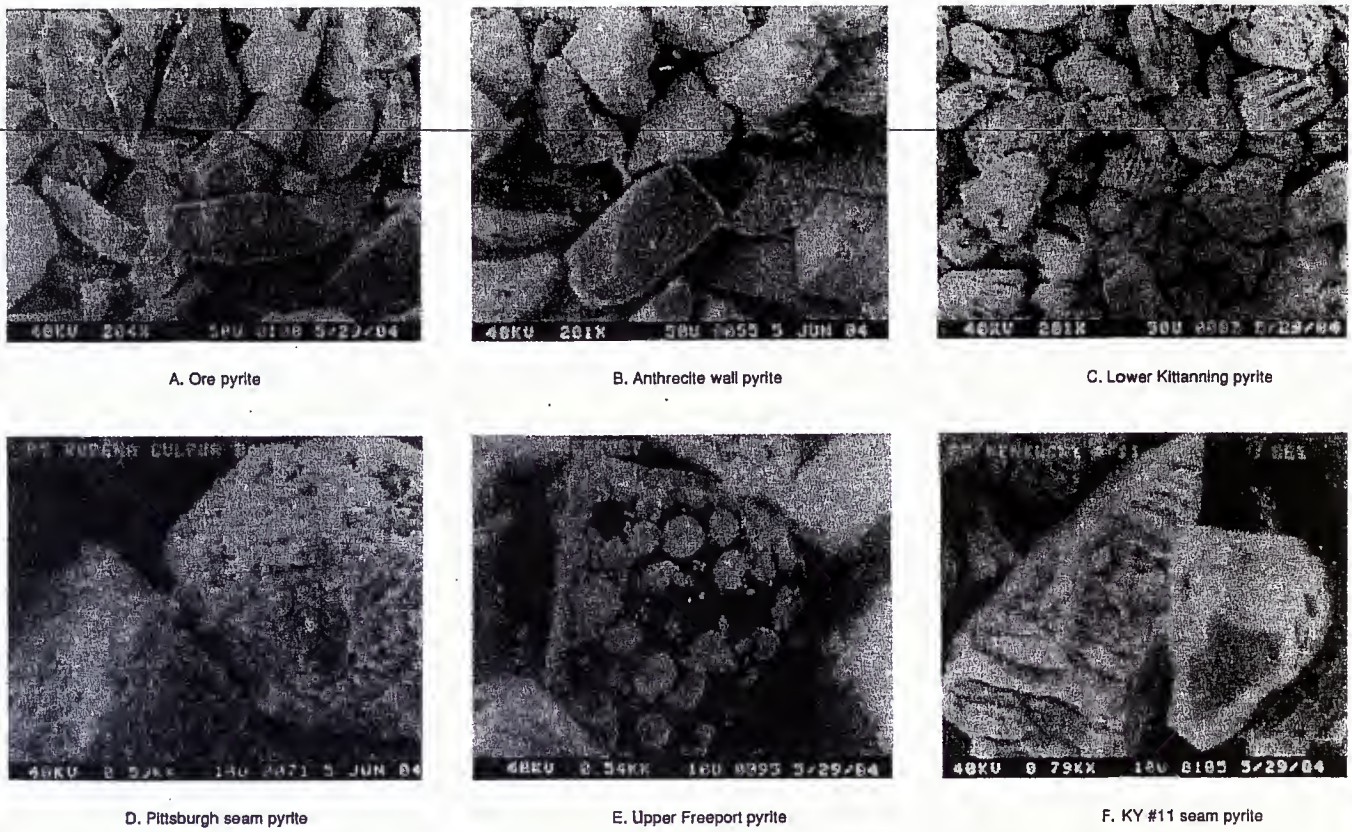
Numerous studies (Chander and Aplan, 1992; Chemowsky

Table 4 — Various properties of pyrites (Esposito, et al., 1987).

Pyrite sample	Apparent sp gr Berman bal.	Optical % anisotropic	Semiconductor type	Surface areas, m²/g*		Inherent flotation % rec.	Morphology**
				Blaine	BET		
Anthracite (wall)	4.86 ± 0.10	35	p	0.0260	0.101	0	SS, PG
Anthracite (seam)	4.74 ± 0.19	50	p	0.0272	0.266	0	SS, PG
Lower Kittanning	3.64 ± 0.21	15	p	0.0323	0.362	7.3	SS, PG, GS, CF
Lower/Middle Kittanning	3.53 ± 0.06	15	p	0.0243	0.854	2.7	SS, PG, GS, CF, FR
Pittsburgh	3.78 ± 0.08	10	p	0.0339	1.502	2.2	GS
Upper Freeport	4.12 ± 0.10	25	p	0.0310	0.951	3.1	PG, GS, CF, FR
KY #11	4.33 ± 0.21	5	p	0.0308	0.597	0	SS, PG, GS, CF
Ore	5.00 ± 0.07	50	n	0.0295	0.045	0	SS

*147 x 37 µm (100 x 400 mesh) particles

** Morphology: SS = smooth surfaces; PG = porous grains; GS = granular or spherical masses; CF = cell fillings and imprints; FR = framboids



A. Ore pyrite

B. Anthrecite wall pyrite

C. Lower Kittanning pyrite

D. Pittsburgh seam pyrite

E. Upper Freeport pyrite

F. KY #11 seam pyrite

Fig. 4 — Morphology of an ore-source pyrite as compared to five coal-source pyrites (Esposito et al., 1987).

and Lyon, 1972; Esposito et al., 1987; Hirt and Aplan, 1991) have demonstrated that coal-source pyrite is very different in its properties and in its response to flotation than is ore-source pyrite. One of the most comprehensive evaluations of the physical properties of coal pyrites, as compared to an ore pyrite, is that of Esposito et al. (1987), given in Table 4. From this table, it can be noted that not only do coal pyrites differ from ore pyrite, they differ from each other.

For example, anthracite is the only coal-source pyrite with an apparent specific gravity (sp gr) even close to the textbook value of 5.01. The coal pyrites studied were all p-type, while the ore pyrite was n-type (although ore pyrites are known to be n- and p-type; Shuey, 1975). The Blaine surface area (that measures only the external surface) shows essentially no variation. However, the BET surface area (that measures the internal and external surfaces) shows that anthracite-source pyrites have two to five times the surface area of ore pyrite, while bituminous coal pyrites are eight to 33 times greater. There appears to be no consistent difference in the optical behavior or the inherent floatability of these pyrites. Esposito et al. (1987) also noted a difference in the oxidation rate and water solubility of these pyrites. The dissolved iron from these pyrites correlated reasonably well with pyrite surface areas and the inverse of the crystallite size.

One of the biggest differences noted from one coal-source pyrite to another is in its morphology. Table 4 shows five distinct morphologies, and four of the samples demonstrate four or more of them. The variation in pyrite morphology may be seen more dramatically in Fig. 4. From Fig. 4C-E, it is obvious why these pyrites have such high surface areas. In fact, the popcorn-like surface of the Pittsburgh seam pyrite (Fig. 4D) results in an especially large surface area. A reduced bulk pyrite specific gravity and an easy dissolution in water would also follow from the pyrite morphology.

Ash mineralogy: While approximately 50 different minerals are found associated with coal (Mackowsky, 1975), less than 1 of these minerals are found in substantial quantities and wid association with coals. Typically, only three or four will hav major significance for a given coal. The coal seam is found t contain mainly kaolinite clay, with lesser amounts of illit quartz and gypsum (O'Gorman and Walker, 1972; Aplar 1988). The preparation plant blackwater from the Easter United States contains about 50% illite and mixed-layer illit montmorillonite clays, with lesser amounts of kaolinite, quar and calcite (Bradley et al., 1980). The latter mineralogy, mo relevant to the preparation process, differs from the ash mine alogy of the seam because of the overbreak of the illite-ric Pennsylvanian shales during mining. Reflecting their differe genesis, Western coal samples were found to contain montmo rillonite and kaolinite clays, together with calcite, dolomite an feldspar (Bradley et al., 1980).

It is important to note the prominence of several of the cla minerals in nearly all raw coal samples. Because of their fir particle size, they may be expected to act like the fluid durin flotation.

Flotation of coal and its associated pyrite and ash-formin minerals

Coal flotation — The problems to be overcome

Coal flotation is a coal cleaning process involving an inte action between the nature of coal and the process variations reagents, operating conditions, machinery and process typ Several investigators (Ragosti, 1970; Klimpel, 1984) have calle attention to this interaction, and it has been a hallmark of muc of the coal flotation work done by the author. The nature of t coal has been discussed in the previous section. What follov has largely been restricted to the froth flotation of coal in t mechanical, subaeration type of cell. By simple extrapolatio

most of the data may also be transferred to column flotation, and they are obviously relevant to the selective agglomeration processes as well.

Using flotation rate, recovery, concentrate grade and selectivity as the principal valuative parameters, the following discussion will address the problems of coal flotation and the rejection of pyrite and the ash-forming minerals. It will be heavily weighted toward the nature of the coal and the influence of reagents and operating conditions.

Based on an initial compilation by Mitchell (1948), the list of potential coal flotation problems has been expanded by the author (Aplan, 1989) to include the following 15 items:

- indifferent results in removing sulfur and ash;
- difficulty in floating low-rank and oxidized coals;
- inability to make clean separations with the finer sizes;
- inability to clean slurries containing a high percentage of clay;
- problems with water chemistry;
- competition with effective, gravity, coarse-cleaning methods;
- low economic value of coal historically;
- dewatering problems;
- transportation and storage problems with coal fines;
- marketing problems with coal fines;
- inadequate attention to the process in the plant;
- inefficient use of capital and operating monies;
- inadequate attention to procedures, machines and processes;
- lack of an adequate R&D program; and
- inertia.

Each of these items has been discussed in detail. However, in terms of those that can be addressed by the experimentalist using flotation, the most important ones are how to effectively float all ranks of coal (including oxidized coals) and how to achieve the selective rejection of sulfur and ash.

The influence of coal properties on coal flotation

Hydrophobicity: Figure 2 is a good guide to the floatability of coal. If the captive bubble contact angle is >~60°, the coal floats readily with a minimal amount of frother. The other coals with a finite captive bubble contact angle are readily floated with a frother and a small amount of fuel oil collector. This oil addition also facilitates the flotation of reluctant-to-float coarse, surface oxidized, less hydrophobic macerals (like fusinite) or moderately locked particles. The sessile drop contact angle is a better predictor of the flotation of coal using a frother-collector system.

Figure 5 indicates that the amount of reagent required for coal flotation increases logarithmically as the %C decreases linearly (Xu and Aplan, 1993). Gutierrez and Aplan (1984) have previously noted a semi-logarithmic relationship between the fuel oil collector and the %C. Brown (1962) had noted a similar correlation, but since he had used a narrower range of ranks and a creosote-type frother-collector, he concluded that the reagent use increased linearly with a decreasing %C.

On a practical basis, coal ranks of hvAb and above use <0.5 kg/t (1 lb/st) fuel oil collector for their flotation. For hvBb and hvCb coals, 0.5-5 kg/t (1-10 lb/st) fuel oil collector are used, while sub and lig coals require >5 kg/t (10 lb/st). Some of these latter coals may require more than 25 kg/t (50 lb/st) oil. Coal flotation using large oil additions also requires special procedures (emulsification, high solids conditioning) or the use of a special collector.

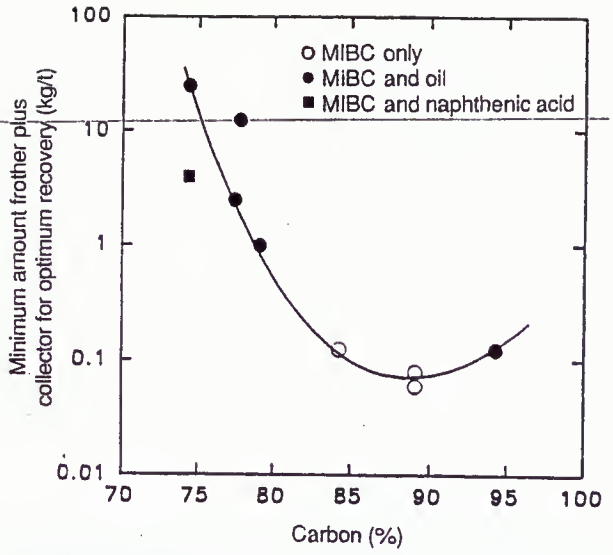


Fig. 5—Minimum amount of frother and collector for optimum recovery of coals of various carbon contents (Xu and Aplan, 1993).

As might be anticipated from the previous discussion of maceral floatability, Western resinite is highly floatable (Klepetko, 1947; Laros and Pick, 1981), while fusinite is much less floatable than vitrinite from the same source (Arnold and Aplan, 1989; Olson and Aplan, 1984). Hirt and Aplan (1991) report the relative floatability of various coal macerals found in an hvAb coal from Eastern Kentucky to be: pseudovitrinite (high reflectance) > pseudovitrinite (low reflectance) > vitrinite (high reflectance) > vitrinite (low reflectance) = micrinite = exinite = semi-fusinite > Eastern resinite > fusinite. Note the great floatability difference between Eastern and Western resinites that is a manifestation of their genesis.

In general, the bottom line in predicting the floatability of a coal from basic hydrophobicity data is the hydrophobicity of the major maceral, vitrinite. From Fig. 2, its hydrophobicity, and hence its floatability, varies in a regular manner with ASTM rank.

Oxidized coal: Oxidation makes a coal act as if it were one of lower rank, with a resulting decrease in hydrophobicity and floatability (Gutierrez and Aplan, 1984). These authors used ambient temperature air or oxygen sparging of the ground coal pulp instead of the furnace oxidation of coal used by most previous investigators. This ambient temperature air or oxygen sparging procedure is believed to be more relevant to the actual situation encountered in coal stockpiling or preparation. Highly hydrophobic coals (lvb, mvb and the upper range of hvAb; essentially the coking grade coals) can tolerate some oxidation without serious floatability loss. However, lower ranks are strongly affected by oxidation, and their loss of floatability increases progressively with a decrease in rank.

The extent of oxidation may be determined by using a boiling caustic solution to extract soluble oxidized products from the coal. The more severe the oxidation, the darker the resulting filtrate. This test was developed by Lowenhaupt and Gray (1980) for coking coals and has been extended to all ranks by Gutierrez and Aplan (1984).

Humic acids, containing a plethora of COOH and OH groups, are dissolved from low-rank and surface-oxidized coal particles. Their presence can seriously depress coal flotation (Sun, 1954; Arnold and Aplan, 1986).

Interestingly enough, anthracite flotation actually improves with gentle oxidation with chemicals, air sparging or

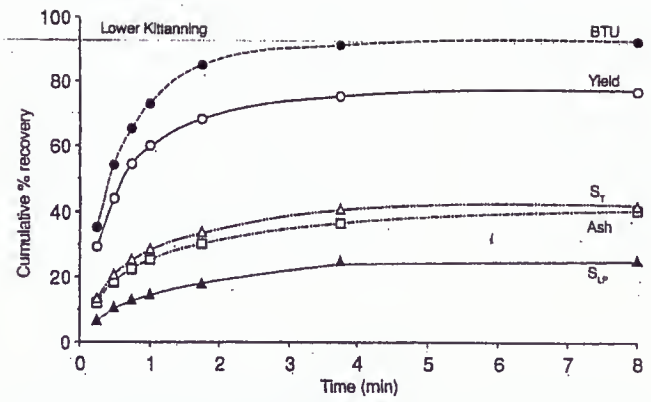


Fig. 6 — Flotation of various constituents in Lower Kittanning raw coal as a function of time (Purcell and Aplan, 1991).

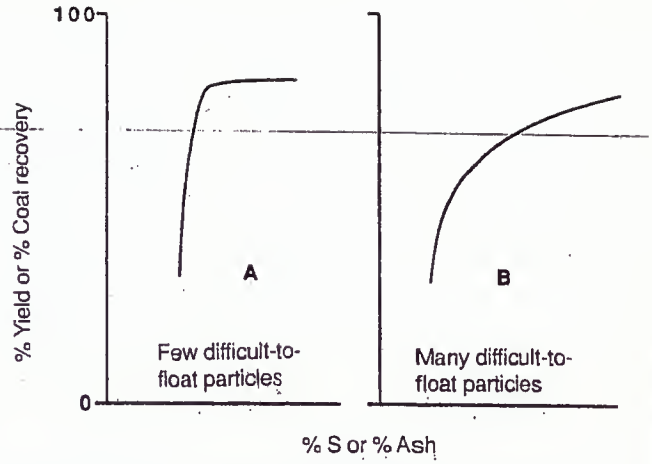


Fig. 7 — The change in the shape of the grade-yield curve in the absence and in the presence of locked and other difficult-to-float particles.

furnace treatment (Sun, 1954; Gutierrez and Aplan, 1984). It is postulated that gentle oxidation produces some sites that will allow for hydrogen or other bonding with frothing and collecting reagents.

The deleterious effect of coal oxidation on flotation can often be cured by increasing the amount of fuel oil collector. Seriously oxidized coals of very low rank will require large amounts of oil or, preferably, the use of a specific collector.

Flotation rate: These studies have been strongly emphasized in our research program since its inception a quarter century ago. Many different rate equations have been proposed and used (Aplan, 1977; Arnold and Aplan, 1989a; Dowling et al., 1985; Rastogi, 1970), and more than one dozen of them fit the facts reasonably well. Based on experience in our laboratories, the preferred equation for coal flotation is the classical, first-order rate equation:

$$r = R_\infty [1-\exp(-Kt)] \qquad (1)$$

where:

- r is the fractional recovery of a given component in time t,
- R_∞ is its ultimate recovery, and
- K is the rate constant.

This equation seems to be more tolerant of imperfect data and the vagaries of coal flotation than do the other models (Aplan and Arnold, 1991). Since a well mineralized and flowable froth is not always produced immediately after the onset of aeration, there may be a lag time (Agar et al., 1980; Arnold and Aplan, 1989a; Rastogi, 1970; Rastogi and Aplan, 1985). This lag-time concept may be compensated for by substituting a (t+ø) term for t in Eq. (1).

It should be cautioned that because the various rate equations are formulated differently, the values of K may only be compared to those derived from the same equation.

Differences in the flotation rates of the various species offer an excellent opportunity to achieve selectivity between dissimilar species (Aplan, 1977; Rastogi and Aplan, 1985). From the basic time-recovery data of Fig. 6 (Purcell and Aplan, 1991), the calculated rate constants for yield and BTU recovery are ~1.75 min^{-1}, total sulfur (ST) is 0.98 min^{-1}, liberated pyritic sulfur (S_{LP}) is 0.56 min^{-1} and ash is 0.98 min^{-1}. Although their flotation rates are similar, the BTU recovery curve is greater than the yield curve because of the presence of ~15% easily rejectable ash. The flotation rate based on yield is usually a good proxy for that of the coal (BTU) itself.

Particle size: As might be expected, various coal particles float differently. The situation is greatly complicated by the coal rank, the particle size range treated, the operating variables and the reagent system. Crawford (1936) demonstrated that fine (–74 µm, –200 mesh) coal particles float first, followed by the intermediate (295 µm x 74 µm, 48 x 200 mesh) sizes and, finally, the coarse (+295 µm, +48 mesh) particles. Brown and Smith (1954-55) and Rastogi and Aplan (1985) have quantified this sequence using rate data.

More recently, Raleigh and Aplan (1991) have shown that the top size treated plays an important role in the relative floatability of coal particles. For several coals, they found that as the top size was reduced from –589 µm (–28 mesh) to –147 µm (–100 mesh), floatability increased. However, when it was reduced further to –37 µm (–400 mesh), the floatability decreased. This latter decrease was attributed to the difficulties of many fine particles competing for the bubble surface and to an increased probability of coal surface oxidation.

Several studies (Olson and Aplan, 1984, 1987; Rastogi and Aplan, 1985) have demonstrated that when an excessive amount of oil is used, all of the particles tend to float at about the same rate.

To facilitate the flotation of the coarser coal particles, more oily collector is often used. While this improves the yield, it also increases the floatability of the undesirable, fine particles of pyrite and ash (Aplan, 1977; Olson and Aplan, 1984, 1987; Hiri and Aplan, 1991).

Correlation with specific gravity separations: Specific gravity separations, available from the standard coal washability data, provide a quick approximation as to how the various raw coal particles might respond in a flotation system. Like gravity processes, as the quantity of ±0.1 sp gr material (locked particles and fusinite) increases above 10%, flotation separations may also be expected to be difficult. Of course, flotation is even more complex than gravity separations, because flotation must also confront the complications of poorly floatable particles, floatable gangue minerals and those accidentally collected by the reagent system used.

Besides the use of washability data as a guide, a grade-yield curve, developed from several flotation tests (Fig. 7), will give the experimentalist or plant operator a good idea of the trade-off between coal recovery and the contamination of the clean coal

product by sulfur and ash. An easy separation is represented in Fig. 7A, while Fig. 7B shows a difficult one.

Influence of reagents

The cardinal rule here is that an excess of any reagent is invariably deleterious to the flotation process in terms of the selectivity between the coal and the gangue minerals. In addition to achieving a high coal recovery, an excess of frother or collector will usually encourage a gangue mineral flotation. Furthermore, an excess of a gangue depressant will likely depress the coal.

Frothers: The most commonly used coal frothers have been the short, branched-chain alcohols, and the creosotes, pine oils and polypropylene glycol ethers. Their principal function is to create bubbles, but some of them also collect coal or promote the flotation of pyrite and ash. MIBC (methyl isobutyl carbinol, 4-methyl-2-pentanol) is usually considered to be a benign frother in the flotation of the higher-rank coals, but an excess has been demonstrated to greatly encourage the flotation of pyrite and ash (Aplan, 1976; Bonner and Aplan, 1992; Olson and Aplan, 1987). Creosotes and pine oils are essentially obsolete, but they have collecting properties for coal and often for the gangue minerals. The newer glycol frothers offer advantages in floating coarse coal particles (Klimpel, 1992). Unfortunately, several of these may strongly adsorb onto the coal, requiring a greater quantity to achieve good frothing. The prior addition of oil, however, mitigates this problem by blocking the coal surface to frother adsorption.

Collectors: Their principal function is to improve the hydrophobicity and, hence, the floatability of coal particles. Preferably, they should not also encourage gangue mineral flotation. The most commonly used collector for coal flotation is No. 2 fuel oil, for reasons of effectiveness, cost, availability and convenience. Kerosene is used to a lesser extent, and other collectors are used only sparingly. Collector use is mandatory for the flotation of low-rank and oxidized bituminous coals.

The study of oil's influence on coal flotation has represented a major thrust in our research (Aplan, 1983; Bonner and Aplan, 1992; Gutierrez and Aplan, 1984; Olson and Aplan, 1984, 1987; Onlin and Aplan, 1989; Xu and Aplan, 1993). Based on these studies, the advantages and disadvantages of No. 2 fuel oil are given in Table 5. The inescapable conclusion is that while this reagent is an excellent coal collector, it also encourages the flotation of pyrite and ash-forming minerals. In addition, unless used judiciously, it can lead to a serious selectivity loss.

Table 5 — Advantages and disadvantages of using fuel oil as a collector.

Advantages	Disadvantages
Increases the flotation rate of coal	Promotes the flotation of pyrite and the ash minerals
Increases the flotation of low-rank and oxidized coals	Encourages the flotation of all fine (<~147 µm, 100 mesh) particles
Floats less hydrophobic macerals (e.g. fusinite)	Floats fusinite and carbonaceous shales
Floats locked particles	Floats locked particles
Floats coarser particles	
Serves as a frother extender	
Blocks the coal surface against frother adsorption	

Onlin and Aplan (1987) found that the use of oil improved th hydrophobicity of most coal ranks and extended the range o strong hydrophobicity of coals from ~80% C (without oil) t ~76% C (with oil). Based on an extensive study of the flotatio of a broad range of coal ranks and oxidized coals, these sam authors concluded that for coal flotation, per se, No. 2 fuel oil i the best collector, of nearly 175 systems studied, on the basis o effectiveness, convenience and cost. A common exception t this generalization is the flotation of very low-rank and highl oxidized coals where other collectors are preferred.

One of the most detailed studies of coal collection reporte in the literature is that of Mainhood and Whelan (1955). Mor recently Onlin and Aplan (1989, 1993) have made a detaile study of the collection of coals, ranging from anthracite t lignite, and of oxidized coals. Some of the better collectors fo the low-rank and oxidized coals, in addition to fuel oil, includ dodecane, tricresyl phosphate, tributyl phosphite and som phenols, carboxylic acids and amines (Aplan and Arnold, 1991)

In summary, theoretically, no collector is required for high rank (>~86% C) bituminous coals, although, in reality, a smal amount of oil is commonly used in their flotation. No singl collector is best for all ranks of coal, but No. 2 fuel oil comes th closest to being universally effective. For low-rank and oxi dized coals, the use of one of the more exotic collectors give above may be required.

pH: The classic work on the effect of pH on coal flotation i that of Zimmerman (1948). Working with an hvAb coal, h found a roughly parabolic, pH-recovery relationship. The opti mum recovery was near pH 7-8. It dropped off sharply belov pH ~4 and above pH ~9.

More recent work in our laboratories (Xu and Aplan, 1993 finds that this representation is only approximately true. High rank lvb and mvb coals float well over a broad pH range fron pH ~3-11, centered around pH 7-8 as an optimum. Th Zimmerman plot is a good representation of an hvAb coal. A the coal rank is progressively reduced, the amount of oil require for flotation increases, while the region of maximum floatabilit is progressively reduced to pH ~4. Simultaneously, coal recov ery and the pH range of floatability also decrease. A sub-(bituminous coal was found to require either a massive amoun of oil or the use of a special collector (naphthenic acid), as see in Fig. 5.

Coal depression: In some instances, it may be desirable t float the pyrite and/or ash minerals and depress the coal. A larg number of depressant systems have been evaluated in ou laboratory, and Im and Aplan (1981) have concluded that dextrine (corn, wheat, potato, tapioca, etc.) is the most cos effective coal depressant. An extensive study of the adsorptio and function of the various polysaccharides has been made b Perry and Aplan (1988) and by Esposito-Brick and Apla (1992).

Influence of other process variables

Several of the important process variables, such as frothe and collector concentration, % solids, aeration, agitation an conditioning, have been studied in our laboratories. The pro gressive increase in the frother and/or collector will improv coal recovery at the expense of a substantial increase in th flotation of pyrite and ash (Bonner and Aplan, 1992; Hirt an Aplan, 1991; Olson and Aplan, 1984, 1987; Rastogi and Aplan 1985; Xu and Aplan, 1993). Excess reagent encourages th flotation of the gangue constituents more than it does th flotation of coal. A starvation or slightly higher quantity of given reagent usually represents the best trade-off.

Aeration has been found to be a significant variable in flotation (Hirt and Aplan, 1991; Rastogi and Aplan, 1985). Also, increased airflow is found to increase the coal flotation rate and recovery, as well as the flotation of the coarser (~589 µm, ~28 mesh) coal particles. The flotation rate is related to the airflow rate, Q, by the approximation:

$$K \alpha Q^{0.79} \quad (2)$$

Pulp agitation is strongly influenced by the impeller speed, and aeration and agitation are related by the dimensionless airflow number, NQ,

$$N_Q = Q/ND^3 \quad (3)$$

where:

- N is the impeller speed, and
- D is the impeller diameter.

Rastogi and Aplan (1985) have shown an optimum in coal yield at N_Q ~4 x 10^{-2}, very similar to that noted for ore flotation (Arbiter et al., 1968). Unfortunately this optimum in N_Q also corresponds to the poorest rejection of pyritic sulfur (Hirt and Aplan, 1991).

For a variety of operational reasons, coal flotation is usually done industrially at 3-5% solids, although Crawford (1936) has found the optimum for coal flotation to be at 12% solids. Thickening of the dilute preparation-plant pulp before flotation is exceedingly rare and is usually found only in those plants designed by ore dressing engineers. Evaluating the range of 3.6-17.2% solids, Rastogi and Aplan (1985) found that the coal yield increased with an increase in the solids. This could probably be attributed to a better recovery of the coarser particles. However, the coal flotation rate and the pyrite rejection were best at ~9% solids.

Conditioning of the coal slurry with reagents is rarely practiced as a separate unit operation, and the reagents are often added to a pump sump or a feed box ahead of the flotation process. For the flotation of low-rank and oxidized coals, or to promote the flotation of relatively coarse particles (>~589 µm, >~28 mesh), a separate conditioning step is helpful. For very low-rank coals, it is a virtual necessity, especially to disperse and distribute the large amount of oil used as a collector. High-solids conditioning and pre-emulsification of the oil in water, or in a water-surfactant solution, can substantially improve the coal recovery and reduce the amount of oily collector needed to float lower-rank coals, such as hvcb and sub (Aplan, 1983; Xu and Aplan, 1993).

The best rejection of pyrite (and by implication, ash) is achieved under the gentle operating conditions of low air, low rpm and low reagent levels.

The major defect in most of these studies of process variables is that one variable at a time is evaluated while the others are held constant. Our current research (Ranjan and Aplan, 1993) is to look at interactions due to changes in the variables of frother and collector concentration, airflow rate, grind size and solids.

Selectivity against pyrite and the ash-forming minerals

The rejection of gangue minerals can be achieved by control of reagents (frothers, collectors and gangue depressants), operating variables and the flotation rate of the various species. In general, the reduction of the gangue minerals during coal flotation may be achieved by:

- depressing the pyrite (or ash minerals) and floating the coal;
- depressing the coal and floating the pyrite or ash minerals;
- improved flotation circuitry (cleaners, scavengers, split-feed flotation, etc.);
- froth sprinkling;
- improved machines and processes (modified mechanical cells, column flotation, bubble size control, flocculation, etc.); and
- alternative machines and processes (bubble techniques, agglomeration and selective flocculation techniques).

Research in our laboratories has generally focused on the use of conventional, mechanical flotation cells and circuits. The goal has been to develop an understanding of how the various components respond to process changes and how selectivity between coal and gangue may be achieved through the use of specific depressants for the pyrite or ash minerals. It is the author's belief, however, that all reasonable avenues should be explored, such as the use of froth sprinkling and column flotation that are especially appealing for cleaning use. These offer very attractive research targets, as do the flotation of gangue minerals away from the coal and the use of agglomerative techniques.

Pyrite rejection: The unintentional flotation of pyrite during coal flotation is caused by locked particles, fine pyrite particles, prolonged flotation time, excessive frother and/or collector and conditions promoting the natural floatability of pyrite. In this latter case, the formation of elemental sulfur on the pyrite surface is controlled by the Eh of the system (Chander et al., 1992). In general, pyrite is best rejected during coal flotation by an "easy does it" approach, but a more exhaustive listing would include these comments and conditions:

- coarse pyrite (>295 µm, 48 mesh) particles do not float well under typical coal flotation conditions
- good liberation, few locked particles
- short flotation times
- gentle flotation conditions:
- starvation frother and collector
- nonoily reagents
- low aeration
- low impeller speeds
- appropriate circuitry (split feed, two-stage reverse, "grind and run," froth sprinkling, etc.)
- appropriate column flotation

Pyrite rejection is especially difficult because of a variation in its floatability from source to source. Hirt and Aplan (1991) found that several coal-source pyrites floated faster than an ore source pyrite (2.3 to 5.7 times faster). Also, there was a wide variation in the floatability of coal pyrite, depending on its source.

In addition to the above procedures, it is possible to add specific pyrite depressant. Historically, only a few studies of pyrite depression during coal flotation have been made (Miller 1964; Yancey and Taylor, 1935). Studies in our laboratories include: Arnold and Aplan, 1990a; Chander and Aplan, 1992; Choudhry and Aplan, 1992; Esposito-Brick and Aplan, 1992; Perry and Aplan, 1985, 1988; and Raleigh and Aplan, 1991.

Choudhry and Aplan (1992) have listed the following reagent depression systems:

- alkalis,
- lime and Ca^{+2} compounds,
- oxidizing reagents,
- reducing reagents,
- specific inorganic ions,

- dispersing agents,
- natural and synthetic polymers,
- xanthated polymers and similar compounds,
- special thiol compounds,
- pyrite surface alteration followed by the use of a specific depressant for this new surface, and
- dyes and chelation compounds.

In considering pyrite depression, the experimentalist should know that:

- While coal rank dictates the frother-collector system, these reagents may also promote pyrite flotation (oily reagents are especially bad).
- The author and his associates have found no one best pyrite depressant. The best pyrite depressant for one coal is not necessarily the best for another coal.
- All pyrite depressants tested in our laboratories to date also depress coal at a similar or (usually) greater concentration.
- Some pyrite depressants, especially the natural and synthetic polymers, may also improve coal floatability slightly.

Rejection of ash-forming minerals: Clays and other fine particles enter the clean coal froth principally through the mechanism of froth carry-over. Arnold and Aplan (1986) demonstrated that the amount of kaolinite or illite clay entering the froth is roughly what one would expect from the amount of water reporting to the froth and assuming that complete mixing occurs in the flotation cell. When the clay is montmorillonite (bentonite), however, much more enters the froth, and this clay can seriously depress coal flotation. As a consequence, the flotation of Western coals, which commonly contain montmorillonite clay, may pose a serious challenge to the preparation engineer.

In addition to froth carry-over, ash particles may enter the froth through the agglomeration of dissimilar species, "piggy-back" attachment to coal particles, accidental entrapment in the froth mass, specific collection and the hierarchy of their flotation rates as a function of particle size. Fine pyrite, for example, tends to float at about the same rate as coarse coal particles (Arnold and Aplan, 1990a; Olson and Aplan, 1984; Purcell and Aplan 1991).

The deleterious effect of oil may be seen from the work of Olson and Aplan (1987). Using an lvb coal, they found that even after eight minutes of flotation using a starvation quality of MIBC (0.10 kg/t, 0.2 lb/st), ~35% of the pyrite and 53% of the ash were floated. In the first minute of flotation, most of the pyrite and ash particles floated were those particles <37 μm (400 mesh). By contrast, when 0.35 kg/t (0.7 lb/st) of oil was added (greatly excessive), the yield increased at the expense of a substantial flotation of the pyrite and ash constituents. Most of these floated in one minute, including pyrite particles as coarse as 589 x 208 μm (28 x 65 mesh) and ash particles as coarse as 1.17 x 0.589 mm (14 x 28 mesh).

Circuitry: A large number of circuits have been examined, including various combinations of roughing, cleaning, scavenging, two-stage reverse, "grab and run" and split-feed flotation (Aplan, 1976; Aplan and Arnold, 1991; Bensley and Nicol, 1985; Bonner and Aplan, 1992; Purcell and Aplan, 1993). The most effective circuits for coal recovery and the rejection of gangue appear to be the "grab and run," two-stage reverse, split feed or simple cleaning varieties.

Table 6 — Flotation rate constants of various specific gravity fractions of Lower Kittanning coal (after Olson and Aplan, 1984).

Sp gr fraction	Flotation rate constants, min^{-1}		Rate, ratio
	MIBC	MIBC/oil	k_{oil}/k_{MIBC}
	589 μm x 208 μm (28 x 65 mesh)		
1.4 float	1.33	3.70	2.8
1.4 x 1.7	0.40	1.55	3.9
1.7 x 2.96	0.018	0.30	17
2.96 sink	0.0044	0.12	27
	208 μm x 74 μm (65 x 200 mesh)		
1.4 float	2.12	5.99	2.8
1.4 x 1.7	0.76	4.38	5.8
1.7 x 2.96	0.081	0.59	7.3
2.96 x sink	0.085	2.71	32
	74 μm x 37 μm (200 x 400 mesh)		
1.4 float*	2.00	3.25	1.6
2.96 sink*	0.52	1.44	2.8
	–37 μm (400 mesh)		
1.4 float*	2.00	3.38	1.7
2.96 sink*	0.87	2.08	2.4

*Approximate values

Locked particles: Only a few studies have been made c the fate of locked particles in a coal flotation circuit (Arnol and Aplan, 1990b; Olson and Aplan, 1984, 1987). The latte studies are the most comprehensive. In them, the variou timed flotation products were screen sized into severa fractions and further fractionated into specific quantities o

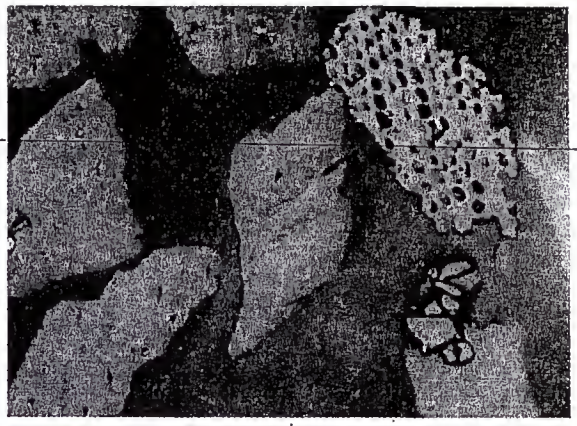
- 1.40 float (essentially coal),
- 1.40 x 1.70 (lighter locked particles),
- 1.70 x 2.96 (heavier locked particles) and
- 2.96 sink (essentially pyrite).

Typical photomicrographs of these specific gravity fractions ar shown in Fig. 8. The major problem is obviously related to th fate of the carbopyrite and fusinitic particles in the 1.4 x 1. fraction. The response of this sp gr fraction in the flotatio process will greatly influence the grade-yield trade-off.

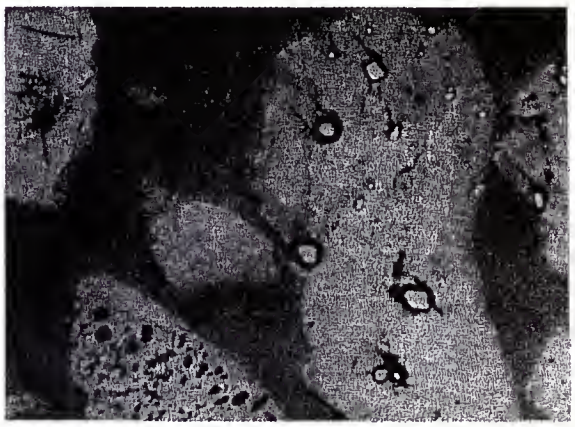
Table 6 shows how various sizes of free and locked particle of an lvb coal respond in a flotation circuit using a starvatio quality of MIBC (0.1 kg/t, 0.2 lb/st) with the further addition c an excessive amount of oil (0.35 kg/t, 0.7 lb/st). The oil cause the 589 x 208 μm (28 x 65 mesh) and 208 x 74 μm (65 x 20 mesh) coal particles (1.4 float) to float about three times faste However, the same sized pyrite (2.96 sink) particles float 3 times faster. For particles below 74 μm (200 mesh), a differer pattern emerges. All particles below 74 μm (200 mesh) hav approximately the same flotation rate (0.5-2 min^{-1}) when MIB(is used and about twice that when oil is added.

Another important pattern also emerges from Table 6. Not that even when a starvation quantity of MIBC is used, the –7 μm (–200 mesh) pyrite floats at about the same rate (1 min^{-1}) a the coarse 589 x 208 μm (28 x 65 mesh) coal. When oil is addec the 208 x 74 μm (65 x 200 mesh) pyrite floats at a similar rate t the 589 x 208 μm (28 x 65 mesh) coal. Fortunately, the coarse: 589 x 208 μm (28 x 65 mesh) pyrite floats poorly under bot conditions. As might be expected, the locked particles above 7· μm (200 mesh) respond in a manner intermediate to those c their two parents.

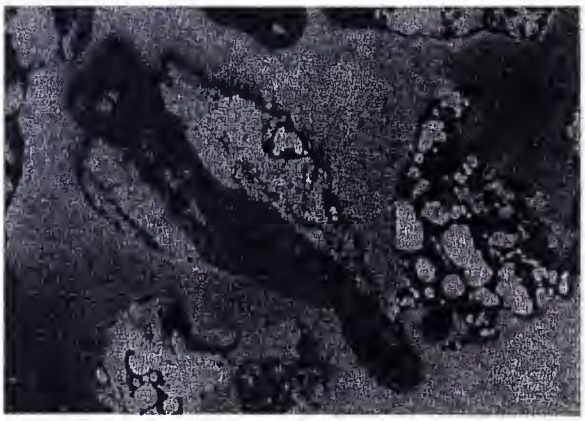
Data from the same source (Olson and Aplan, 1984) indicat

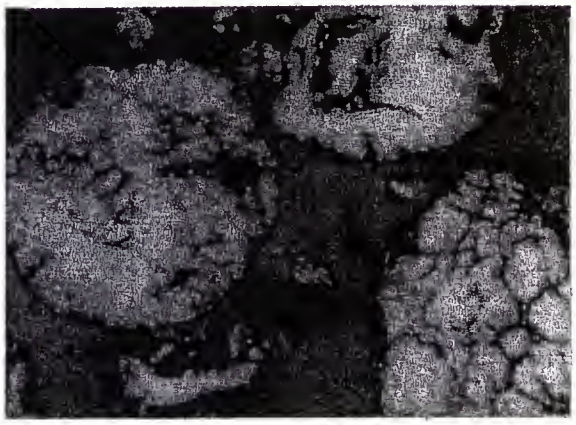


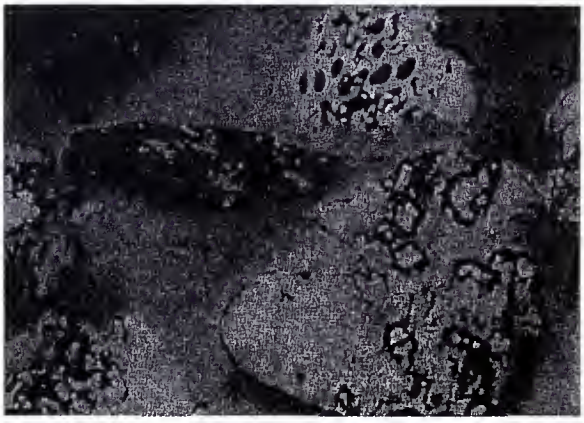
1.4 sp gr float "coal"



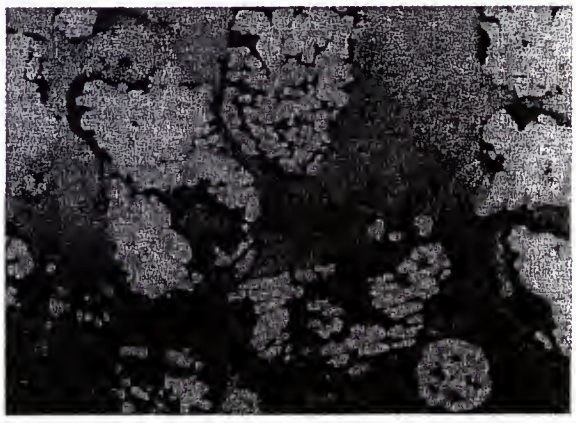
1.4 x 1.7 sp gr lighter locked particles







1.7 x 2.96 sp gr heevier locked particles



2.96 sp gr sink "pyrite"

Fig. 8 — Typical particles of various specific gravities found in lower Kittanning raw coal. All of the particles are 589 µm x 208 µm (28 x 65 mesh) but the magnification varies (Olson and Aplan, 1984).

that flotation selectivity been coal and particles containing fusinite (high ash) or pyrite may be improved by using minimal amounts of frother and a relatively coarse particle size. For all particles >208 µm (65 mesh), the 1.4 float fraction is generally devoid of high-ash fusinite and particles containing visible free ash. Not many of the >208 µm (65 mesh) particles in the 1.4 x 1.7 sp gr fraction float under these same conditions. Reference to Table 6 indicates that flotation can be used to minimize the flotation of the coarser locked particles.

Liberation: For those wishing to evaluate the effect of comminution on pyrite and ash liberation, the work of McCartney et al. (1969) may be used as an estimate. In addition, Perez and Aplan (1987) have developed a simple model to represent the fractional yield of a species (like pyrite or ash) out of a coal-ash-pyrite assemblage.

The fractional yield of species, A, is:

$$A = Y_A(x) = ae^{-x/\mu} \qquad (4)$$

where:

- x is the particle size, and
- a and µ are constants.

Summary

Coal flotation is a complicated process, but it is subject to rational interpretation. Very fortunately, coal properties are usually dependent upon rank parameters, as is coal flotation. The following guidelines should be helpful:

- Know your coal.
- Know the general geologic and geographic genesis and location information and the special properties associated with these circumstances.
- Know the coal rank. From this, its physical and chemical properties may be inferred.
- Know the sulfur content and forms — pyritic, organic and sulfate.
- Consider any special circumstances such as:
  - oxidation,
  - pyrite and ash mineral constituents, their quantity, distribution and properties, and
  - user constraints.
- Know the strengths and weaknesses of the flotation processes and the reagents used.
- Know the user constraints so that grade-yield trade-offs can be properly evaluated. ♦

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